TEXT FLY WITHIN
THE BOOK ONLY

UNIVERSAL
LIBRARY

OU_166482

UNIVERSAL
LIBRARY

GENERAL BIOLOGY
PALAEONTOLOGY
AND
ZOO-GEOGRAPHY

By

B. B. GUPTA

Ex-Professor and Head of the Department of Zoology,
MAHARAJA'S COLLEGE, JAIPUR.

ROY & CO.
BOOKSELLERS AND PUBLISHERS,
10, Faiz Bazaar, Daryaganj,
DELHI.

Published by:
ROY & CO.,
10, Faiz Bazaar, Daryaganj,
DELHI.

FIRST EDITION : 1958

Printed by :
JAIPUR PRINTERS
JAIPUR.

PREFACE TO THE FIRST EDITION

The scope and purpose of this book is to make available to the University students a handy volume containing complete exposition of the various theories of Evolution, Variation, and Heredity, together with chapters on Zoogeography, and Palaeontology. The justification for its publication in these days of over-production lies in the fact that students do not find all these topics dealt with in a single book, and wherever these topics are referred to, they are usually in bulky volumes with which few readers have the time or courage to grapple.

The book is based on my actual teaching-experience of University classes, extending over thirty six years, and aims to be comprehensive in its scope. Its object is not simply to stuff a student's mind with facts but to give him just what he requires to know and learn about the various topics dealt with in it, and no more. I have purposely avoided giving unnecessary details lest they may lead to confusing and overtaxing the brain, and thus thwart the very purpose for which the book is primarily intended for. I claim no originality in writing this book—there is probably not a new idea in it, but only an attempt to explain matters of abiding interest and importance for Degree Students in as simple a style as possible.

I am deeply indebted to my friends and Colleagues, Miss P. Khanna, M.Sc. of Maharani's College, Jaipur, for the labour of preparing the manuscript and seeing it through the press, as also for the continued inspiration she gave me in completing the book, and Shri V. S. Shivpuri of Maharaja's College, Jaipur, for the use of books he kindly lent me from the College library.

B. B. Gupta.

CONTENTS

PART I

General Biology

Chapters. *Page.*

I. History of Evolution 1

II. Evidences in Support of Evolution ... 4

III. Factors of Evolution–Lamarckism ... 10

IV Charles Darwin and Natural Selection ... 15

V. De Vries and Mutation Theory ... 20

VI Variations 26

VII. Heredity 32

VIII. August Weismann and Continuity of Germ-plasm 36

IX. Gregor Mendel and his laws ... 41

X. Mimicry 51

XI. Inheritance of acquired characters ... 58

XII. Recapitulation hypothesis ... 65

PART II

Palaeontology

XIII. Sedimentary Rocks 71

XIV. Fossils and how they are formed ... 82

XV. Conditions in which Fossils occur ... 84

XVI Usefulness of Fossil study 87

XVII. Imperfection of Geological Record ... 89

XVIII. Archaeopteryx 92

Ancestry of Horse 94

PART III

Zoo-geography

XIX. Factors influencing distribution ... 101

XX. Zoological Life-realms 109

Palaearctic Region 111

Nearctic Region 112

Ethiopian Region 113

Oriental Region 114

Australian Region 115

Neo-tropical Region 117

XXI. Discontinuous Distribution 119

CHAPTER I

HISTORY OF EVOLUTION

If we ask how the living plants and animals that we know, have come to be what they are—very numerous, very diverse, very beautiful, marvellous in their adaptations, harmonious in their parts and qualities, and approximately stable, we probably receive answers in the following theories:—

Theory of Eternity :

According to this plants and animals have been as they are—it argues for the unchangeableness of the Universe, holding not only that organisms have been unalterable throughout their existence, but that they have always existed and will continue to exist in the same unchanging state throughout eternity.

This was apparently the belief of very few authorities, for one finds no allusion to it in the literature of science.

Theory of Special Creation :

Another theory contents itself with the statement that each species has come into being independently by a process of *Special Creation.* It is a simple story, beautifully told, derived from the Hebrew tradition and well suited to the state of knowledge of the times and of the people for whom it was written. This account has heen the teaching of the Christian Church authorities for many centuries.

Upholders of this doctrine maintain that first plants and animals, like those now surrounding us, were made and fashioned from the soil, dust or earth—all had been clay in the hands of the potter. In many mediæval sculptures the deity is represented as moulding with his hands the semblance of a human figure out of a shapeless lump of clay.

The theory further maintains that each kind of plant or animal was not only created as a separate kind and in a state of full prefection, but was specially designed to suit the conditions under which it was placed; the fish was created to swim in the sea, the horse to run on dry land, the monkey to climb on trees, the birds to fly in the air, and each was constructed in accordance with its foreseen requirements. So profound was the influence of this doctrine upon European Catholic thought that its teachings continued to be the only orthodox belief in Europe until the middle of the 19th Century.

Theory of Catastrophism :

Still another theory, the theory of *Terrestrial Revolution* as it is known, was given to the world by Cuvier (1769-1832), one of the founders of the science of Paleontology, According to it there had been several creations in the history of the earth and that each, at the end of its period, had been wiped out by some cataclysmic upheaval and a fresh set of organisms created on different lines.

This belief was held by later scholars of the same school and not apparently by Cuvier himself, who believed that these new faunas are not created on the spot, but come from distant regions.

This theory retained its position for half a century and was completely overthrown by geologists led by Charles Lyell (1830).

Theory of Organic Evolution :

Such a view of the origin of living things has at the present day been entirely superceded by the doctrine of organic Evolution which teaches us that species of kinds are not immutable but are subject to changes, whereby one may give rise to another, and that existing species are the more or less modified descendents of pre-existing ones- i.e. the present is the child of the past in all things, that the plants and animals now existing arose by a natural evolution from simpler pre-existing forms of life, these from still simpler and so on, back to the mist of life's beginnings.

The idea conveyed by the definition of Evolution itself means that whereas, in the earlier and lower forms of life, one organ performed many different functions in an imperfect manner, evolutionary development has gradually produced higher forms in which each function has its separate organ by which it is more perfectly discharged. Thus evolution has been an ascending process from the lower to the higher, from the less to the more organized.

Some inkling of this process can be traced in the writings of the Roman poet Lucretius who lived about 98-55 B.C. The same thoughts, differently expressed, are apparent in the much earlier teachings of Empedocles (about 490-430 B C.), Greek philosopher and physician. In the times of Aristotle the idea had reached quite a respectable degree of development.

In the middle ages all useful thought upon the subject was annihilated by the adoption of the Jewish Cosmogony by the Christian Churches, and it is not until the end of the 17th Century that we find thoughtful persons beginning to struggle against the ecclesiastical bondage. It was then that the seed was sown which has at intervals brought forth recurrent crops of evolutionary hypothesis based on general reasoning.

Various attempts have been made to explain the way in which evolution has come about—more important of which are associated with the names of Buffon (1707-1788), Erasmus Darwin (1737-1812). Lamarck (1744-1829), Charles Darwin (1809-1882) and Wallace (1823-1913).

The evidence in favour of the existing species of animals and plants having arisen by a process of evolution is of a most ample and convincing kind, but evolution can claim to be a scientific truth only so far as clear evidence is forthcoming that evolution there has been.

CHAPTER II

EVIDENCES IN SUPPORT OF EVOLUTION

Palaeontology :

This can be learnt from the history of life upon the earth as disclosed by the evidence of *Paleontology* or the Geological record. It is an evidence by which alone can the truth about evolution be scientifically and satisfactorily established.

From the study of the various strata of the earth and of the fossils found therein it has been made clear that in the lowest strata the traces of only the simplest organisms like protozoa, coelenterata and sponges have been discovered. As we gradually ascend to the subsequently formed rocks we come across, besides the simpler type of type, a greatly increased complexity in the organization of animals—the most complex or highly evolved being present only at the top. The order of the occurrence of the fossils, therefore, furnishes a very strong proof of *Organic descent.*

From the examination of fossils of the various periods one striking fact emerges: that each period has certain predominating types of organisms; such organisms did occur earlier as well as later in geologic time, but they attained pre-eminent position in the life of their era. This seems to show that, in the history of life, certain types of organisms have appeared, increased in numbers and variety of forms until a maximum was reached, after which a decline set in, the premier place being taken by some other form.

This is truly an evolutionary process—the types of animals as represented by the successive pre-dominant forms, appear in a series of progressive complexity of organization.

The most famous instance of geological evidence, as showing and proving evolution to demonstration, is that of the *Modern horse.* The fossilized remains present a moderately complete series of changes during the evolution of one animal to another (Eohippus, the dawn horse of Eocene with five digits, of which one was vestigial, to the Equus or modern horse running on the tips of the middle digits only).

Classification of animals :

The theory of evolution finds its broadest inductive foundation in the natural classification of living things, which arranges all the various forms in larger or smaller groups according to their degree of affinity. These groupings—species, genera, family, order, class etc., show such constant features of co-ordination and sub-ordination that we are bound to look on them as genealogical and represent the whole in a genealogical tree. This tree-like form assumed by the natural classification bears an unmistakable resemblance to the tree-like development of the whole organic world which evolutionists believe to have taken place.

Comparative Morphology and Anatomy :

The survey of a series of types of animals shows that they are all built upon the same general plan which is modified in different directions in the several instances. Throughout the vast series of animals we find in different guise essentially the same parts twisted into most diverse forms for different uses, yet all referable to the same fundamental type--the hands of a frog, a rabbit, a horse, a bird and a man are all built upon one plan, though the parts are of different shapes in the several classes-there is a similarity of design, and this can only be explained by assuming that the groups possessing it originated from a common stock.

On the hypothesis of special creation we should expect a whale to have fewer vertebrae in its neck than the giraffe, but both have seven cervicals inherited from some common ancestor.

The whole internal structure of the human body agrees so closely with those of other mammals that their external differences are of no account whatever. We can understand and explain it only when we regard the internal resemblances as an inheritance from some common stem-form, and external differences due to adaptations to different environments.

In the same class of evidence we may place the existence of *Vestigial organs*, such as the muscles of the pinna, vermiform appendix, coccyx, and hair on chest etc., of man, which can only be satisfactorily explained on the supposition that they were functional in an ancestor, and have persisted as relics of past history, comparable, as Darwin said, to the unpronounced letters in many words.

Embryology :

The fact that the young organism can not commence its existence at the stage reached by its ancestors, but has to make a fresh start and go through a whole series of stages before reaching the adult condition, is very significant from the stand-point of organic evolution.

The embryos of animals of one great class or even phylum present remarkable similarity to one another. In later stages of development there are considerable differences, but in the earlier the corresponding stages are so closely resembling that in many cases it is difficult to distinguish between them.

Besides in the course of its ordinary development one of the higher animals usully exhibits, in successive stages, features permanent in forms lower in the scale.

When we examine a human body in the third or fourth week of its development, we find it to be quite different in shape and structure from the full grown human being, but almost identical with that of the ape, the dog, the rabbit, and other animals at the same stage of ontogeny. Prior to reaching the mammalian shape the human ovum at first approaches very closely to the anatomic structure of a lancelot, afterwards to that of a fish, and again to the typical build of an amphibian, later on to a reptile, and in further advanced development it takes on its special mammalian characters.

The frog, in its own development, passes through a tadpole stage which is to all intents and purposes a fish.

The embryological investigation leaves no doubt as to the general truth of the recapitulation hypothesis, and must convince any unbiassed observer that, however much modified it may be, the life-history of the individual is essentially a condensed epitome of the ancestral history of the race--this can only be explained in terms of organic evolution.

Geographical Distribution :

Among the chief phenonmenon that bear witness to the inductive law of evolution we have the geographical distribution of the various species.

If there were such a thing as creation, a particular species would be the same everywhere. There must have been birds of the same type in India as in Australia, and there would have been a mixture of the species, and no gradation in the species of animals could be possible.

But differences in the faunas of various parts of the world, even when the two regions are similar in climate, as England and New-Zealand, are facts that have no explanation in the theory of special creation, and are easily explained on the supposition that the course of evolution has been different in the two cases owing to different histories in the past geologic times.

Changes under Domestication :

The evidence from domesticated animals is of a very convincing kind. Numerous breeds of horses, cattle, sheep, dogs, and pigeons etc., have been produced by careful inbreeding of varieties, pleasing the fancy of man—all often distinguished from one another by structural differences more profound than those which separate two natural species In great measure domestic breeds are fertile with one another, while different species rarely are.

The numerous and very diverse breeds of domestic pigeons, which are all derived from the rock-dove, clearly illustrate the plasticity or variability of organisms. Wallace has remarked "If there is an equal chance of the occurrence or origin of new forms in Nature. and under cultivation, then their survival until a stage at which they can be readily recognized as distinct from the original type, should be more frequent in Nature than in cultivation, because the former has a large population to work with."

Observed facts of Mutations :

Mutations are new forms of animals that appear all of a sudden and continue to reproduce their kind. New or more or less conspicuous characters appear suddenly and spontaneously, without any obvious reasons.

Professor Hugo de Vries attributed great importance to Mutations as the starting points of new species, which were responsible for effecting progress from the lower towards the higher. Thus mutations strongly support the idea that animals modify and transform into others. Such, in mearest outline, is the nature of the evidence that leads us to conclude that the various forms of life have descended or have been evolved from simpler ancestors, and these from still simpler, and so on, back to the mist of life's beginnings.

None of the evidence is logically demonstrative; we accept the evolution idea because it is a plausible interpretation which is applicable to many orders of facts, and is contradicted by none (Thomson).

CHAPTER III

FACTORS OF EVOLUTION

The evidence in favour of the existing species of animals having arisen by a process of evolution is of a most ample and convincing kind, but the point to be discussed is "was such evolution genetic? Was it wrought by descent with modifications of form from form? In short what were the factors inducing evolution?" These have been differently advocated by Naturalists, and thus evolution becomes a different creed in the hands of its various exponents.

Amidst the causes which bring about the modification of species, Buffon attributes great importance to the *action of the climate*—"changes are slow and imperceptible, little by little they become evident and express themselves at length in results about which we cannot be mistaken". He also realized the importance of the principles of use and disuse and the inheritance of acquired characters, which were destined to take a prominent place in the subsequent writings of Lamarck. He had also anticipated views of Malthus and Charles Darwin with regard to the importance of the struggle for existence and the process of natural selection.

J. B. P. Lamarck 1744-1829 :

The great French Philosophical Biologist, Jean Baptiste Pierre Antoine de Monet Chevalier de Lamarck, was largely influenced in his views by the writings of Buffon with whom he was on terms of personal friendship. He was professor of Invertebrate Zoology in the National Museum of France, and was also an experienced Botanist, and had published many important Botanical works. His most famous work the "*Philosophic Zoologique*" was published in 1809, in which he maintains that the first living things arose by a process of spontaneous generation, and from the starting point thus provided the entire animal and vegetable kingdoms have arisen as the result of orderly and progressive evolution.

Noticing that the organs of man and other animals are increased and strengthened by use, and particularly by conscious use, Lamarck assumed that this effect could be passed on by inheritance from parents to offsprings, and so accumulated from generation to generation. He conceived the production of new specific forms to take place due to great changes in environment, which lead to great changes in the requirement of animals. Such changes lead necessarily to a change in their actions. If the new requirements become constant, animals adopt new habits by constant repetition of similar actions i e. use of some particular part of the body in preference to some other, and in certain cases, complete disuse of some part.

Lamarck startled the thinking and still more the unthinking world, by suggesting that if characters acquired by use and disuse of certain parts were gradually handed on for long enough, there appeared another kind of plant or animal, a creature with specific characters marking it out from all others. This was the first blow to the school of thought which believed in a ready made creation.

Domestic ducks can no longer fly like wild ducks as their power of flight is inhibited. If seeds that are natural to a damp meadow, be transported first to a slope of a neighbouring hill (where soil is sufficiently cool) and afterwards, after having lived there and reproduced, they reach, by slow degrees, the dry and almost arid soil of a mountain region, and if the plants succeed in living there, they will become so changed that the botanists would make them a distinct species.

As other examples in support of Lamarckism mention has been made of the elongated neck and limbs of *Giraffe*, that have been effected by continuous stretching for many generations. Living in wild places of Africa there was a constant exertion brought about by the search of food. Food was limited and was to be had only on the upper portions of trees, when all the leaves on the lower portion were exhausted by other animals. There was struggle for existence and those that could bring about an elongation of their anterior limbs and necks, survived. *Shore-birds* obtain their food for sometime on the shores, but in time their number increases and food diminishes. They strive to enter water—those with elongated legs get a distinct advantage so that their feathers may not get wet.

When the entire surface aquatic fauna is exhausted and used up, birds with long beaks are able to take food from lower level.

In *snakes* there is an elongation of the body accompanied with the loss of limbs. They had the habit of creeping through narrow holes and crevices, and the limbs were a check in their forward progression. Their ancestors that happened to possess the longest and thinnest bodies and the smallest limbs had a distinct advantage over their fellows.

Flat fishes live at the bottom of the sea where they have no light. They lead an inactive life, lying on one side of the body. The eye of that side has therefore migrated to the other in order to be useful.

A *Mole* has very small eyes because it had ceased to use them; the whale-bone whale has no functional teeth because it has acquired the habit of swallowing its food without mastication.

Lamarck attributed considerable influence to the use and disuse of organs. He was able to place the theory of organic evolution on a much firmer and broader basis than it had previously enjoyed.

His Two Laws :

He held that in every animal that has not passed beyond the term of its development the frequent and sustained use of any organ strengthens it, develops it, increases its size and gives it strength proportionate to the length of time of its employment. On the other hand the continued lack of use of the same organ sensibly weakens it, deteriorates it, and diminishes its faculties progressively, until at last it disappears. He further held that nature preserves everything that she has caused the individual to acquire or to lose by the influence of circumstances to which the race has been, for a long time, exposed, and consequently by the influence of the predominent use of certain organs or by that of the constant lack of use of such part, she preserves the change by heredity and passes it on to the new individual that descend from it.

There is a great deal of justification for a belief in the operation in nature of the *environmental influences* on the organisms and *use and disuse* of organs, but there are certain difficulties in the way of acceptance of the truth of *transmission of acquired characters,* for which convincing proof is still lacking. Prof. Lankester pointed out that Lamarcks' first and second laws are contradictory the one of the other. The new character, which is exhypothesi as was the old character that it has replaced, is, according to him, all of a sudden raised to extraordinary powers—it is declared to be transmissible. Since the old character (length, breadth, weight, etc.) had not become fixed and congenital after many thousands of successive generations of individuals having developed it in response to environment, but gave place to a new character, when new conditions operated on an individual, we cannot accept that the new character is likely to become fixed after a much shorter time of responsive existence.

Professor Poulton states "Lamarcks' first law assumes that a past history of indefinite duration is powerless to create a bias by which the present can be controlled; while the second law assumes that the brief history of the present can readily raise a bias to control the future."

One of the weakness in Lamarcks hypothesis appears in his illustration of the snake. If we should grant that inheritance of the effects of disuse of the legs might possibly explain their absence in snakes, still it would not explain the origin of the snake's desire to glide—that is as much a characteristic of the snake as the absence of legs.

The hypothesis could apply only to the animal kingdom, since plants in general have no nervous and muscular activities like those of animals. A hypothesis of organic evolution, to be valid, must apply equally to both plants and animals.

Lamarckism is therefore incomplete in itself as an all-embracing cause of evolution.

CHAPTER IV

CHARLES DARWIN (1809-82)

Darwin is beyond doubt the foremost figure in evolutionary history—a methodical painstaking English Naturalist with a broad vision. His statements were accompanied with abundant proof. His arguments were always inductive and not deductive like those of Lamarck, and he had made theory every where subservient to fact. The clarity and simplicity of his exposition made his arguments irresistible and accomplished the wide acceptance of his doctrine. He first studied in Edinburgh and subsequently entered Christ College at Cambridge. His love of nature dominated all other interests, and shortly after graduation in 1831 he got an opportunity to join the ship "Beagle" as a naturalist in a voyage of exploration around the world. He explored South America, Galapagos Islands, and other regions, and was for five years on the voyage. On his return he became ill, and this necessitated a retired life which was of great indirect benefit to the Zoological world.

Many of the facts of animal distribution and of the relations between living and fossil animals, learnt in his travels, led him to consider the origin of species. The clue to the method of evolution first dawned upon him in 1838 while reading Malthus on "Population". Malthus had emphasized the fact that the number of human beings in the world were increasing in geometrical ratio, while the food supplies increased much less rapidly in arithmetic ratio. Therefore, argued Malthus, the time will soon be reached when there will be no food enough for all, man will then struggle for actual existence and only the fittest (strongest, fleestest, most cunning or clever) will survive.

In pondering this hypothesis Darwin atonce saw its larger application. It struck him that favourable variations would lead to be preserved and unfavourable ones to be destroyed under these circumstances. In 1844 he wrote out a summary of his theory, but continued to gather furthur data from original researches and observations by himself and many other persons, and finally in 1856 he had completed his manuscript embodying a theory of evolution of which Natural selection was the prime factor and sent it to Sir Joseph Hooker, the botanist. In 1858, however, he received a brief essay on the same subject from Alfred Russel Wallace who had independently arrived at similar conclusions. Darwin was inclined at first to suppress his own work and publish Wallace's to the world, but on persuasion by Charles Lyell and Hooker a joint paper was read before the Linnaean Society of London. Later Darwin wrote the most famous work "The Origin of Species" that was published in 1859.

Darwinism :

Darwinism may be defined as a certain rational causo-mechanical explanation of the origin of new species. The Darwinian explanation rests on certain observed facts and certain inductions derived from these facts.

The observed facts are :

(1) *Increase by Multiplication in Geometrical ratio* of the individuals in every species, whatever the kind of reproduction may be:

Amongst fishes the number of eggs laid by them is enormous: 20,000 in herring, six million in Cod, 9 million in Turbot, and 20 million in Ling. If all these eggs were to develop into adults, only one single species of fish would fill the entire ocean.

An Oyster lays 60 millions eggs; if the entire progeny survived and multiplied, giving rise to great great-grand children, the heap of shells would be eight times the size of the earth.

House-flies similarly would occupy a space of about a quarter of a million cubic feet at the end of one summer.

If all descendants of a microscopic animal like paramœcium, reproduced in five years, were put together, the volume of protoplasm would approximately equal ten thousand times the volume of the earth.

Even the slowest breeder, an elephant (that produces only six young in its life of one hundred years) would in the space of 750 years, multiply to 19 million descendants, which would make a long array, going one and a half times round the equator, giving 20 feet for each.

(2) The always apparent slight variation in form and function existing among all individuals, even though of the same generation or brood. Variations are natural and they are neither adopted nor inherited. No two individuals are alike—even the children of the same parents differ.

(3) The transmission, with these inevitable slight variations, by the parents to the offspring, of a form and physiology essentially like the parental.

The facts inferred from these observations are :

(i) There is neither room nor food for all the new individuals produced as a result of geometrical multiplication, and consequently there is a competition between all organisms and between each individual and its physical environment, leading to a "*struggle for existence.*" This struggle may be intraspecific or interspecific or environmental (excesses of moisture or draught, extreme heat or cold, lightening or tempest, earthquakes and volcanoes, cyclones and floods, epidemics, and accidents). Without destruction it could not have been possible for so many species to exist, as only one single species would have otherwise occupied the whole earth.

(ii) The probable success in the competition of those individuals whose slight variations are of such a nature as to give them an advantage over their contemporaries, which results in saving their life, atleast until they have produced offspring. Some members of a species are necessarily less fitly adapted than others, and the course of nature is such that these relatively less fit forms will tend to be eliminated while the relatively more fit will tend to survive—This is *"survival of the fittest"*.

(iii) The saved individuals, by virtue of the action of heredity, hand down to the offsprings their advantageous condition of structure and physiology. The resultant of these conditions is an inevitable "Natural selection" of individuals and species. As many variations re-appear generation after generation and may become gradually increased in amount, the continuance of the selection or eliminating process will work towards the origin of new modifications, always towards adaptations, towards fitness, towards a moulding of the body and its behaviour to safe conformity with external conditions.

Thus there are brought about through a purely mechanical and inevitable weeding out and selection by nature, through uncounted generations in unreckonable time, the exquisite adaptation of the parts and functions of animals and plants. The survival of the fittest is therefore the result of natural selection that enforces adaptation. This is Darwin's causo-mechanical theory to explain the transformation of species and the infinite variety of adaptive modifications.

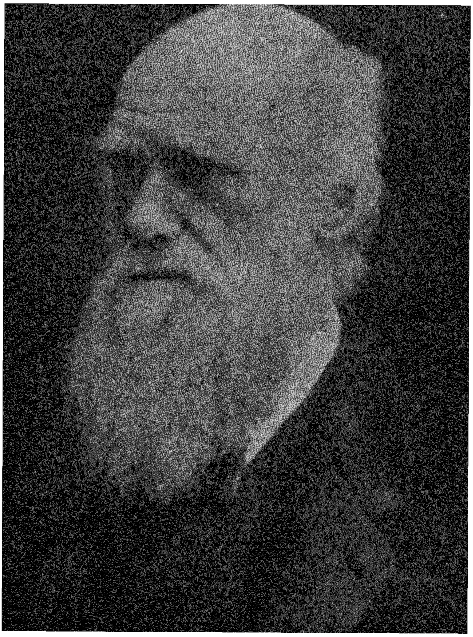
Several objections to natural selection have however been offered. The chief among them are the following:

(i) It is difficult to imagine a reason why variation tending in an infinitesimal degree in any special direction should be preserved.

(ii) It is almost impossible to conceive how the first rudiments of important organs—wings, eyes, mammary glands and numerous other structures—could have been of any use, and if they were not of any use, they could not have been preserved and further developed by natural selection.

(4) The geologic time has been too short to give selection opportunity to do its work.

(5) Darwinism left us with a very large and fundamental problem unsolved-"upon what material does natural selection act in the formation of species?" Obviously the fittest survive, but what is the origin of the fittest ?



CHARLES DARWIN
His epoch-making work "The Origin of Species" was first published in November 1859.

(6) The power of regenerating a lost part must clearly often be of service to the creatures possessing it. Such a power may in many cases be considered to be a well marked adaptation. Morgan pointed out that there are insuperable difficulties in the way of adopting the belief that such a power can have been acquired through the action of natural selection.

(7) No one has ever observed a new species developing from another—this ought to be possible if evolution by natural selection is now in progress.

(8) The presence of apparently useless and vestigial characters finds its explanation extremely difficult on this theory.

Such are some of the reasons which, on purely rational grounds, appear amply to justify those who decline to pledge their faith in Darwinism inspite of the popularity it enjoys.

CHAPTER V

HUGO DE VRIES AND MUTATIONS

Side by side with the famous Darwinian doctrine a new school of thought was springing up, that had no faith in evolution by natural selection but believed in evolution of new species or of new specific characters by sudden marked changes appearing in the offspring of a normal parent—these large changes take place at a single step by a discontinuous method.

The actual observations of such discontinuous variations are of quite recent date, and their recognition is largely due to the exertions of Bateson (1894). He had made the first definite attempt to collect and coordinate these facts, but De Vries primarily worked out in detail the hypothesis that discontinuous variations furnish the material upon which natural selection operates. His theory that mutations explain the origin of the fittest is popularly known as the *Mutation Theory*, according to which species have not arisen gradually as the result of selection operating for hundreds or thousands of years, but discontinuously by sudden however small changes.

De Vries was the Director of Botanical Garden in Amsterdam, Holland, and was amongst the first to demonstrate that the method of experiment could be applied to the study of evolution. His plan was to secure seeds of a given species, pure with reference to a given character. The character of parent plant was noted and recorded—the plants of second generations were done likewise and so on. Accurate comparisons were made to see if any individual showed a tendency to vary widely from its parents in any significant way.

In 1886 De Vries found a large number of plants of evening primrose, Oenothera Lamarckiana, in an abandoned potato field. A year later he found two perfectly definite forms, one *short-styled* and the other *smooth-leaved* with smaller petals than the parent. He carefully isolated them and observed that both of them produced offsprings like themselves, and continued to breed true.

Numerous other aberrant forms, that bred true, were further observed by him—*Oenothera-gigas* that had twice as many chromosomes as the parent form; the appearance of *white flowers* among a crop of red-flowered poppy; *Green dahlias; Green roses; red sun-flower*; *white black-birds* and other albinos; *thornless* plants among thorned ones; *rayless* compositeæ; *fringed celandine* among plants of greater celandine; *purple* beaches among ordinary beaches; *double-flowers* among carnations, stocks, petunias and roses, arising from single flowering plants; and so on. A historic case was the sudden appearance of a true breeding stock of *red-eyed* Drosophila of one *white-eyed* individual, and similarly of a male lamb with long sagging back and short bent legs among a flock of sheep owned by Sethwright. This became the ancestor of the Ancon breed of sheep. Domestic breeds have, according to De Vries, arisen discontinuously as definite novelties, and artificial selection started usually bys taking hold of some prominent modifications on which to egin working. As a result of fairly extensive series of ex-h emqperiments on plant breeding, De Vries summarised observations as follows :—

(1) New species arise suddenly at a single step, without transitional forms.

(2) They are usually fully constant from the first moment of their origin.

(3) A considerable number of individuals of the same sort usually make their appearance at the same period.

(4) Although the new types vary in a normal fashion and frequently transgress the limits dividing th

from the parental type, their first appearance has nothing to do with continuous variability.

(5) Mutations take place indefinitely, showing no tendency in any particular direction.

(6) The tendency to mutate periodically re-occurs.

The view of De Vries with regard to the actual origin of new species may be summed up as follows :—

Broadly speaking species arise by mutations by a sudden single step in which either a single character or a whole set of characters together become changed. In the former case a new *variety* results, in the latter a *new species.*

Kinds of Mutations :

Mutations are of several kinds :

1. *Progressive Mutation*—An entirely new character or set of characters make their appearance, after a more or less latent period or permutation period. It is by mutation of this kind that De Vries believes the main divisions of animal kingdom to have been built up.

2. *Degressive Mutation*—In which there is a return of a character that was formerly present in the past history of the race but which has for generations been absent. Castle's four-toed race of guinea-pigs is an example of this.

3. *Regressive mutation*—These are characterised by the dropping out of some thing—as albinism is caused by the absence of pigment. Albino mutants that breed true are well known particularly among mammals such as rats, mice, rabbits cats, guinnea-pigs and even man himself. It is thus quite apparent that De Vries theory and experiments very well support his doctrine for which Bateson had accumulated a considerable amount of evidence. These facts clearly show that species in nature arise by sudden and definite steps of great amplitude.

The first person to formulate a more or less precise view upon the subject of definite variation was Francis

Galton, although he never entered into the question at any great length. He has very well expressed his idea of the existence of *stable forms*, such as may be supposed to have arisen by large and sudden steps, in his division of variations into three groups of **Primary** types, **Sub-ordinates** types and mere deviations from the latter.

Distinction between primary and subordinate positions of stability is excellently illustrated by a model known as the Galton's polygon A B C D E.

The first position of the model resting on the side A B may be taken to represent a stable form, A comparatively small push (variation) will lead to the production of a subordinate type B C, but it is easier to cause the model to turn to its original position A B. A strong push (mutation) may however force the model to pass through the position C D until it comes to rest on the side opposite A B. This fresh position represents stable form and it is now once more surrounded by positions of subordinate stability or sub-types.

Slow variations cannot bring about a complete overturning to a stable form.

We may compare the difference existing between *deviations* and *stable forms*, arising by fluctuating variations and by definite variations respectively, with the behaviour of the atoms of chemistry as expressed in the account of their structure given by Professor J. J. Thomson:

Such an atom, he says, is made up of a number of electrons having a definite relation to one another in space. Under certain circumstances a number of such electrons can be removed, one at a time from the atom. It is found that each successive removal of an electron changes the properties of the atom in a gradual and progressive direction. But after a time a point is reached at which the removal of one more electron upsets the equilibrium and a new arrangement takes place to regain the lost equilibrium-this would completely alter the properties of the atom itself.

In like manner we can assume the chemical composition of the living substance of a new race to be altering step by step—every such step being accompanied by comparatively unimportant changes in its visible characters, until the time comes when a little further change must be associated with a deep-seated revolution in the substance of the living matter, and with a correspondingly marked *mutation* in the external features of the animal and its progeny.

Value of Mutation Theory :

(i) The mutation theory is not intended to supplant the theory of natural selection but to demonstrate that the materials upon which selection acts are mutations only and not fluctuating or individual variations.

(ii) Mutations offer a method by which evolutionary changes may take place within a much shorter period than was demanded by natural selection of slow and continuous variations.

(iii) Incidentally the mutation theory clearly shows that the absence of connecting links between species is no argument against evolution but is on the contrary just what we might expect to find.

(iv) It is of great service to breeders. It has shown that results of great commercial value donot require a lifetime, but may be obtained within two or three seasons.

Objections to Mutation Theory :

1. It is absurd to attempt to account for the sharp discontinuity in the series of mature individuals by supposing that each member of it has suddenly come into existence full grown.

2. It is extremely hard to believe that mutation can have afforded sufficient opportunity for all marvellous

adaptations that exist in nature. Mutual adaptation between the length of nectary in certain flowers and the length of the proboscis in insects which fertilize them, can not be accounted for by mutations, unless they took place simultaneously in the same locality and in a sufficient number of each—a supposition that is wildly impossible.

3 Mutations cannot account for the presence of flight-less birds on oceanic islands.

4. If it be argued that mutations may be so small as to be inperceptible, they come to resemble fluctuating variations; and if it be told that they occur very rarely and donot fluctuate, they could have hardly given rise to adaptive modifications. Protective resemblance and mimicry can only be due to the accumulation of slow and successive variations under natural selection.

Mutation theory is thus based on false premises, but we must not be swung to the extreme and take one-sided view, but keep our course in the middle and wait and see the future results.

CHAPTER VI

VARIATIONS

All scientists and naturalists are convinced of the truth of evolution, but they differ markedly in their views on the ways and means whereby it has been brought about. Evolution has thus become a different creed in the hands of its various exponents—these ways and means are the *factors* of evolution.

Variation is the first and most fundamental progressive factor in evolution. Without it no change could occur, and evolution would be impossible. The whole process of organic evolution depends upon variations.

The living things on the earth present an almost inexhaustible array of differences. If every detectable difference be recognized, it is probably true that no two organisms are alike—even the offsprings of the same parents differ. A child is not found to be his father's "double". In measure, however slight, he differs. This difference between the begetting and the begotten might conceivably be due to the fact that the surrounding circumstances or environment of the one were not precisely identical with those of the other. But even when the environment is the same for both, this difference is still found, and we express it by the general term '*variation*'.

The central secret of life is the origin of the new, just as the central secret of the musician or the painter is his creativeness. Among the delightful birds called "ruffs" there are seldom two males alike. That is what is called variability. Each ruff is unique—itself and no other, and so is with every child. There is no child in the world like its parents-it may not be the strongest, the cleverest, the prettiest, the best behaved, but it is unique. The differences among the members of a family are often extraordinary—and this again is variability.

The term includes not only material differences, but also those whose only demonstrable expression is psychical. Just as there is no one method of the origin of species, so there is no one type of variation. Different evolutionary agencies differ in intensity and sometimes in kind in different sorts of organisms, partly owing to differences in the environment, partly to differences in the way of life, and partly to differences in genetic machinery. Variations include not only morphological characters like size and colour, but also physiology and behaviour etc.

The first group is based upon the conceptions of Weismann—it is owing to him that we classify variations into two fundamentally distinct categories—*modifications* and *Mutations*. Modifications are produced by alterations in the environment, mutations by alterations in the substance of the hereditary constitution—Weismann termed them as:—

(a) Somatogenic or acquired, and

(b) blastogenic or germinal.

The two other contrasting groups are *continuous* or *Discontinuous*, and *Determinate* or *Indeterminate*.

Somatogenic Variations :

Those variations which affect the body of the organism and are acquired in the life-time of the individual are known as Somatogenic. They are due to extrinsic influence of a change in environment or function—changes in surrounding pressure, in food supply, in heat or light *etc.* may be followed by corresponding changes in the organism upon which they play. Addition of specific chemical reagents to the water, in which aquatic larvae are developing, produces such definite and extensive modifications of structure as to give rise to veritable monstrosities: Eggs of Fundulus fish, subjected to magnesium-chloride dissolved in sea water, develop larvae with a 'cyclopean eye' in place of the ordinary pair. Similarly the bodily structure of an animal may be profoundly changed by the increased use of certain parts or the disuse of others. This change in function may be directly influenced by changes in the external conditions of life : long neck of giraffe, elongated legs and beaks of shore-birds, loss of eyes in cave-dwellers, better development of the muscle of the right hand and the right side of the chest of a black-smith *etc*, are all changes due to function

Blastogenic Variations :

. As contrasted with these Somatogenic variations are Blastogenic or Germinal variations which arise as a consequence of some modifications of germ-cells They are, from their very nature as attributes of the germ-cells, handed on by heredity from generation to generation. Such variations are also termed Constitutional or Congenital. They arise in the germplasm itself due to recombinations or new groupings of the germinal factors or genes at every new act of fertilization of an egg cell by the spermatozoon, and the changes involved.in and preparatory to this fertilization.

The changes that are the result of the individual experience—the result of the series of relations between the individual and the environment—are fitly to be termed 'adaptations' or 'acquirements.' The more familiar phrase is "acquired characters." Variations or new inborn characters are unquestionably transmissible by heredity, else there could hardly be any organic evolution, but the transmission of acquirements is a matter of keen controversy.

The occasional occurrence of supernumery digits in man, the horse, cat and other animals, is a germinal variation, for they cannot be due to accident or to any external influence, and are occasionally inherited through several generations On the other hand the loss of a digit in man, through too close proximity to a circular saw, is an acquired characteristic; and it has been experimentally proved that such variations are intransmissible—they die with the individual in which they occur.

Continuous Variations :

These comprise small graded deviations from the typical condition of the species, and which fluctuate on either side of a typical condition. They pass into one another by small or even insensible gradations. They are generally quantitative rather than numerical variations, and the increment of change between successive generations is extremely slight. Changes in height, colour, and odour are cases of such continuous or fluctuating variations. They fluctuate about a mean, and may be illustrated by the bob of a swinging pendulum, which continuously fluctuates about the mean position, right and left.

Such variations are dependent upon environment, and they have a number of transitional forms. The general tendency is for each individual to conform to the type of the species to which it belongs, but many accidental circumstances combine to prevent the realization of this tendency, and deviations take place in accordance with the laws of chance.

Discontinuous Variations :

As contrasted with continuous variations are discontinuous variations or *Mutations* or *sports*, in which new or more or less conspicuous characters appear suddenly and spontaneously without any obvious reason. They deviate more widely from the type of the species, and there is much greater variety of their occurrence. They do not fluctuate about the old mean or average condition, but about a new one of their own—such as the seeds of a red-flowered species bear flowers that at one step have become pure white; from odourless plant one or more seeds may give rise to plants with sweet scented flowers; and the numerous instances of variations from the standard number of digits in vertebrates (hexadactylism), and the arising of hornless cattle in a herd of horned ones, giving rise to hornless progeny, etc.

New species arise suddenly at a single step and without transitional forms, and they are usually fully constant from the first moment of their origin.

Indeterminate Variations :

Variations are further classified as Indeterminate or those fortuitous variations which are not subject to any law but which occur in any conceivable directions of change. Such variations may give a distinct advantage to its possessor in its successful fight in the struggle for existence. It is upon such variations that the Darwinian factor of natural selection is supposed to operate.

Determinate Variations :

Nothing definite can be said about Determinate Variations. There seems to be no such tendency to vary always in a given direction in successive generations.

Still others have classified variations as *Meristic* or *Numerical*. In majority of organisms certain parts are repeated with a greater or less degree of regularity and constancy, and it is upon this repetition that the symmetry of the organism very largely depends. A starfish is usually 5-rayed and radially symmetrical. Meristic variation may give rise to 4-rayed or 6-rayed individuals; a clover leaf has usually three leaflets but occasionally four leaflets have been discovered. These variations have been contrasted with *substantive variations* which depend upon the structure—shape, size and colour of the organism or its parts. Total height of the individual, shape of nose, ear, and fingers, colour of eyes and hair, are all subject to great variation. All these methods of classification obviously overlap one another-thus a meristic variation may be continuous or discontinuous, somatogenic or blastogenic, and so on Variations that are of the nature of adaptations in response to external conditions do not play any role in evolution. The highly raw materials of evolution are the germinal or blastogenic variations. It is, however, likely that some of the more deeply saturating results of the ever varying environment may act directly on the germplasm and thus bring about heritable change.

Weismann explained true variations as due to the direct action of external influences upon the hypothetical "biophores" and "determinants" of the germ-plasm. The relation between the germ-plasm and their environment is nutritive. Weismann supposes the constituent structures of the germplasm to undergo incessant changes of composition during their residence in the body of the individual, and these changes are the essential causes of variation. The immediate cause of these changes is to be found in the "inequalities of nutrition" to which the determinants are subject.

Various experiments conducted by Dr. Vernon on the sex cells of sea-urchins, by Cossar Ewart on the rabbit, and by De Vries on plants, seem also to support the view that the germ-plasm is affected by "inequalities of nutrition.".

CHAPTER VII

HEREDITY

After variation *Heredity* is the second fundamental conservative factor in evolution. A new character arises by variation, but heredity causes it to persist. The mere variation of the *individual*, howsoever profound or beneficial, is not evolutional until it can be handed down from parent to the offspring, and this is the function of heredity.

Some consider heredity as the force which compels the resemblance, while others consider it as the process whereby offspring comes to resemble its immediate ancestors.

Like tends to beget like, and the offsprings usually resemble their parents and their ancestors. It is not only that the general characteristics may be transmitted, but minute features, idiosyncracies, pathological conditions, inborn in the parents, may also be transmitted to the offspring. Heredity thus obviously includes two different processes: The transmission of the factors of inheritance or genes, and the reappearance of characters in successive generations. Organisms are moulded as the result of the inter-action of the environmental stimuli and the germinal constitution. Every character is the product both of factors of inheritance and of environment, and can only be reproduced when both are present (Goodrich). The main object of a theory of Heredity is to express the nature of the genetic relation which binds generations together and to interpret the facts of inheritance in terms of this relation.

The cells of which a multicellular body is composed become differentiated and specialized in various directions according to the part they play in the economy of the organism. In so doing the vast majority of them lose their faculty for independent existence. When their power of division has become exhausted, the tissues into which they are combined become worn out and ultimately die. Thus the body or soma must suffer death sooner or later. The only cells which are, even potentially, exempt from this fate are the *germ cells*—these remain as independent protista and have the power of separating sooner or later from the parent body.

In as much as the only possible connection between parent and offspring is through the germ-cells, it follows that there must be something in these germ-cells which represents all the inheritable characters of the parents, and is capable of giving rise to a repetition of these characters in the course of individual development.

The great problem that has to be solved by any theory of heredity is "how do the apparently simple germ-cells of a multicellular organism come to be representative of all the cells of the body ?"

It seems that there are only two possible ways in which this marvellous fact can be explained :

1. All the somatic cells are so intimately connected with the germ-cells that each of the latter bears within itself the influence of whole of the former.

2. We may look upon the germ-cells as directly developed from the germ-cell from which the parent arose. Parent and offspring would then resemble each other, because they are produced from the same thing, although at different times.

In accordance with the first hypothesis the germ-cells may bear the impress of every event which happens to the somatic cells during the life of the parent, and such characters may therefore be looked for in the offspring; while with the second the offsprings and parents can only resemble each other in characters that were predetermined in the germ-cell from which the parent arose.

Pangenesis Theory :

The first theory, maintaining that a close relationship of a natural kind exists, throughout life, between somatic and germ-cells, was suggested by Darwin under the name of *Pangenesis theory,* in 1868.

It was put forward as a provisional hypothesis to explain the facts of heredity, and though it seems never to have met with any large measure of acceptance, it is of considerable historical interest. The chief suggestions of this hypothesis are:

1. All the constituent-cells of the body not only multiply by cell division, so as to build up the new tissues, but also give off throughout life extremely minute particles, known as *gemmules,* which wander through the body.
2. These gemmules become specially concentrated in the germ-cells in both sexes.
3. Each germ-cell is in a sense a minute replica of the parent's body, and is capable of developing into the same kind of a body, even in minute detail.
4. These gemmules are thrown off at all stages of development.
5. There is a sort of continuous competition in the germ-cells between the original gemmules and the new arrival, and according to which wins the old or the new form develops.

With this hypothesis every somatic cell is a germ-cell, while the germ-cells proper are merely the meeting place for the germs of somatic cells.

This theory leads to an almost infinite complexity of a germ-cell, containing as it does a material particle or gemmule from every somatic cell.

If this theory were true, we should expect that mutilations such as are inflicted early in life, would be transmitted to offspring. There is however no evidence of the transmission of mutilations. In cases of transfusion of blood it seems reasonable to suppose that some of the gemmules of the donor will be carried over and get collected in the germ-cells of the individual that received the blood, and that thus some characters of that donor would afterwards appear in the offspring of that individual. But careful experiments have proved that such transference of heredity characters does not accompany the transmission of blood.

This theory leads to the acceptance of the teachings of Lamarck or even of Buffon.

Later researches, however, proved that such a theory has no basis in fact, and biologists soon began to search for a substance which could be a physical basis for heredity, just as protoplasm is the physical basis of life. It remained for August Weismann to identify and demonstrate its existence.

CHAPTER VIII

HEREDITY *(Continued)*

August Weismann (1834-1914) :

August Weismann was for nearly fifty years a professor in the University of Frieburg. He did not believe that variations are natural, and attacked the basic Lamarckian thesis of the transmission of acquired characters. He postulated that characters acquired in the life-time of an individual can not be passed on to the offsprings, and that effective changes could only take place through the germ-cells. Relying on his amazing powers of intuition rather than on the facts actually known to him, he located the physical basis of inheritance in the Chromosomes.

His celebrated theory of heredity is based upon what he terms *"the continuity of the Germplasm"*. Germplasm, according to Weismann, is that part of a germ-cell of which the chemical and physical properties, including the molecular structure, enable the cell to become, under appropriate condition, a new individual of the same species. Weismann divided all the substance of an organism into two parts: *Germplasm* and *Somatoplasm*, the protoplasm of the germ-cells being the actual vehicle of heredity. The word "continuity" is employed to express the theory that heredity depends upon the fact that a minute quantity of this germplasm is reserved unchanged during the development of the individual, and subsequently grows and gives rise to the germ-cells. Hence the germplasm is continuous from one generation to another in unending succession, and from it the germ-cells of each generation are produced. None of the somatic cells, however, have any share in subsequent generations.

Amphimixis :

Variations are brought about by the Union of germ-cells of two different sexes, and in case of animals where there is no sexual union, variation is not much marked. Chromosomes have different traits, and different chromosomes unite with each other—there is thus a different union of different characteristics retained in different chromosomes. The process may be likened to two miniature packs of cards, each of which is elaborately shuffled, one half the cards rejected and the remaining halves combined into a new pack. This gives rise to an enormous number of possible recombinations. If packs contain forty eight cards, the number of possible permutations will be 16,777,216—no wonder the children of a family differ !

The theory involves the assumption of great complexity of structure in the germplasm. There exist not only '*determinants*' which correspond more or less closely to Darwin's Gemmles, and each of which is supposed to be responsible for the development of some special inherited feature of the organism, but also of structural units of a lower and higher order – thus each determinant is supposed to be made up of still smaller units '*biophores*' which are themselves the lowest vital units but each of which is in turn made up of molecules in the chemical sense of the term; and the determinants are supposed to be grouped into units of a higher order "*ids*" each of which is a complete ancestral germplasm, sufficient in itself to determine all the different characters of an entire individual. Each 'id' contains all the possibilities—generic, specific, individual of a new organism.

During maturation of germ-cells a considerable part of the egg-cell is removed by the discharge of polar bodies, and the same results from the reduction division of the sperm-cells. By this the possibility is created of producing through the germ-cells, very various combinations of the hereditary tendencies, and therefore an actual high degree of variability in the offspring.

Because in each reducing division of the germ-cells their ids are lessened by one half, the possibility exists of gradually removing the ids of disadvantageous variation from the germ-plasm of the species (for in each generation the offsprings of the disadvantageous id combinations are extinguished by natural selection), so that, from generation to generation the germplasm gradually becomes purified of the disadvantageous ids, while the favourable combinations produced by amphimixis are retained A new shuffling of the cards, therefore, must take place in each generation. The characters of the organism, developed from any zygote, will depend upon the hand dealt out to it in the processes of reduction and amphimixis, and as it can rarely if ever happen that any two hands will be exactly alike, so it will rarely if ever happen that any two organisms will exactly resemble one another in all their characters.

We therefore find in the process of reduction and amphimixis, in the permutation and combination of ancestral characters, an abundant source of variation.

As there is continuous stream of germplasm from generation to generation, to which the somatic cells contribute nothing, only those mutations which are germinal in their origin can possibly be handed down, and as the hereditary stream of germ-plasm is already set apart before the adult body is in use, one cannot see how any modifications impressed upon the latter through use or disuse or extrinsic adaptations to environment can possibly become a part of the organism's heritage. (*cf. Inheritance of acquired Characters*)

Criticism on Weismann :

1. This conception is strictly evolutionary and is a reversion to the general opinion of biologists of the seventeenth and eighteenth centuries who regarded that the germcells contained an image in little of the adult, and that the process of development is a mere unfolding of this under the influence of favouring and nutrient forces.

2. There is no direct evidence for the existence of differentiating as opposed to doubling divisions of the nuclear matter.

3. The occurrence, in higher plants, of tissues with power of reproduction, the occurrence of budding in almost any part of the body in lower animals and plants, and the wide spread powers of regeneration of lost parts, are easily intelligible if every cell, like the egg-cell, has been formed by doubling division and thus contains the germinal material for every part of the organism, and hence, on the call of special conditions, can become a germ-cell again.

4. It is argued that every organism is a physiological as well as a morphological unity, and that cells entirely insulated within such a unity (as germ-cells according to Weismann are) would be a physiological miracle.

Principles of Inheritance

Students of heredity have worked out a few definite principles of inheritance with which, under certain conditions, organisms seem to conform. The most interesting ones are ;

Galton's Law—Galton's statement about ancestral inheritance is that "an organism of bisexual parentage derives one half of its total heritage from its two parents (one fourth from each), one fourth from its grand parents, one eighth from its great-grand parents and so on. All these successive fractions added together equal one, i.e an individual derives half its characteristics from its immediate parents and the remaining half from its more remote ancestry.

$$1/2+1/4+1/8+1/16+1/32+1/64+\ldots\ldots\ldots\ldots=1$$

This has been shown to be only a general approximation of the actual inheritance relations.

The *law of filial regression* states that the offspring of exceptional parents tend to regress towards mediocrity in proportion to the degree of the parental exceptionalness. If the immediate parents, or one of them, differ markedly from the average condition of the race in any particular character, the offspring will have a tendency to inherit the particular character but not to the same extent, for the influence of the grand-parents and other ancestors will tend to counteract that of the parents and cause a partial return or regression towards mediocrity. In the words of Karl Pearson. "It is the heavy weight of this mediocre ancestry which causes the son of an exceptional father to regress towards the general population mean. It is the balance of this sturdy commonplaceness which enables the son of a degenerate father to escape the whole burden of the parental ill."

Oscar Hertwig :

Besides the two theories of heredity, Darwin's theory of Pangenesis and Weismann's 'Continuity of the germplasm, a third and most recent theory is that of Oscar Hertwig. He denies the existence of a cardinal distinction between germplasm and the plasm that goes to form the individual body. He observes that in higher plants there are tissues that have power of reproduction; though these tissues are definitely distinct from the special reproductive tissues which contain the "germplasm" of Weismann. Further in many of the lower animals and plants budding is possible in almost any part of the body; also, there are the facts of regeneration and repair. All these facts are intelligible if we presume that *every cell* of the body "contains the germinal material for *every* part of the body, and thus, on the call of special conditions, can become a germ-cell again." Hertwig supports his theory by very numerous and varied experiments. These appear to show that when embryonic organisms are exposed to abnormal conditions their cells can be made to undergo unusual forms of development and take to functions other than those observed in other conditions. The inference is that no particular cells are unalterably predestined for the reproductive or any other function, and that the environment can cause them to devote themselves to the functions of the germ-plasm.

CHAPTER IX

HEREDITY *(Continued)*

Gregor Mendel:

STUDENT OF HEREDITY
Gregor Mendel (1822-1884), whose broad generalities on heredity are known as Mendel's law.

Gregor Johann Mendel was the first person to conduct decisive experiments in heredity and to formulate the basic fundamental laws that govern inheritance in plants and animals. The whole question of inheritance had assumed a new aspect, first on account of the work of DeVries with regard to the appearance of discontinuous variations in plants, and secondly on account of Gregor Mendel as to the laws of inheritance of discontinuous variations. Mendel was son of an Austrian peasant who belonged to a family of gardeners. After schooling he joined Augustian Monastery at Brunn in Bohemia, but his weak health made him unfit for the work. A year later he became a teacher of Mathematics and

Biology, and became interested in the problem of inheritance. He recognised heredity as a factor of major importance for understanding organic evolution. He saw clearly that the earlier experimenters had neither traced individual characters through successive generations nor kept complete numerical records of their results. To overcome these difficulties Mendel planned careful experiments in breeding, and carried them out for eight years, and spent two years in selecting races with distinctive and contrasted characters and in making certain that each of his original stocks was pure. He then made many crosses by artificial pollination and kept an accurate statistical record of plants and seeds of each kind that was produced, analyzed these results, and from them deduced two most important fundamental laws of heredity, now known as *Mendelism* or *Laws of Mendel.*

His memorable paper called 'Researches of Hybrid Plants', in which the mechanism of heredity was accurately set forth, was published in the journal of a small local Natural History Society in 1865, where his work remained burried and un-noticed till long after his death, perhaps due to the fact that the biological world was then occupied solely with the discussion of the 'origin of species' published only seven years before. His conclusions were, however, independently rediscovered in 1900 by three other investigators, and it was only then that they came to world-wide attention. Mendel selected for his experiments garden peas, of which there are a number of well-marked varieties, such as tall and dwarf, yellow and green-seeded, purple and white-flowered. Having proved that his plants came true from seed, he studied the results of crossing forms with these clearly contrasted pairs of alternative characters and followed them through several generations.

When tall and dwarf strains were crossed the resultant seeds all produced tall plants. They were not intermediate in height, and there was no suggestion that any thing which could govern dwarfness had been passed on from the other parent—the character of tallness being independent of the character of sex. But when the hybrid plants were allowed to set seed by self-pollination, dwarfness reappeared in roughly a quarter of the offspring, the rest being tall. The proportion of the tall variety to the dwarf was 3 to 1 There must therefore have been concealed in the hybrids some factor which could make plants dwarf, otherwise they would not have been able to pass it on to some of their descendants. It could only have been derived from the dwarf parent of the hybrids. This factor he called a '*Germinal-unit*' or 'Gene', and he maintained that these germinal units remained unaltered in the gametes even when the character did not appear in the adult.

Mendel described the factor which made for tallness in peas as being *dominant* (or mastering) with respect to its opposite factor which determines dwarfness. The latter he called *recessive* (or disappearing) because it apparently vanished in the first hybrid generation.

To find what was the meaning of this three to one proportion of the two types Mendel allowed the representatives of the second generation to be self-pollinated. He found that the dwarf plants bred true, as did one third of the tall plants. The remaining tall plants behaved like the original hybrid, producing tall and dwarf plants in the proportion of three to one.

Let us suppose that the pure tall plant has a pair of genes 'TT' for tallness, and the pure dwarf plant the genes 'dd' for dwarfness. The sex cells produced from these plants will carry only one of the pair of genes 'T' or 'd', and hence when the two are crossed the hybrid will come to possess two different genes for the trait in question i.e. tallness; but when two hybrids are crossed, some of their offspring will show the effects of one gene and some the effects of the other—the characters of which no vestige appeared in the first generation (hybrid) are not, therefore, necessarily lost, for in second F_2 generation—i.e. in the offsprings of the hybrids—the recessive characters reappear.

Tall 'T' × Dwarf 'd'.........Tall hybrid 'Td'.

Td × Td

TT Td Td dd

In representing the genetic make-up, or genotype, of an individual, capital letters are ordinarily used for dominant genes and lower case letters for recessive genes. A dominant gene will always show its effects in the physical characteristics, or phenotype, of an organism, even though the recessive is present; the recessive gene expresses itself only when the dominant is absent as in 'dd'.

The expression "1A: 2Aa: 1a" in which 'A' represents the dominant character, and 'a' the recessive character, may be spoken of the MENDELIAN FORMULA.

As he saw, these results can only be explained on the theory that sex-cells can only carry one or the other of the alternative characters. The original tall plant produces germ cells or gametes bearing tallness; the dwarf plant produces gametes bearing shortness. The F_1 (first generation) therefore contains both conditions—its cells may be regarded as double structures, consisting of a double set of determinants for the various characters of the plant, one of each pair derived from male and the other from female

Parents	TT or DD
Sex cells of parents ...	All 'T' or all 'D'
Hybrid	TD (appears tall)
Sex cells of Hybrid ...	Equal number of eggs— T or D Equal number of sperms—T or D
Possible matings of egg and sperm when Hybrid is self-pollinated ...	Equal number of: TT ... Tall DD ... Dwarf TD } DT } Tall but are of same nature as Hybrid.

When the zygote gives rise to gametes it produces some bearing tallness, and other bearing shortness, but *none bearing both*—these gametes are formed in equal numbers. Since large number of gametes are formed and since they meet indiscriminately in fertilization, a tall will equally often meet a tall or a dwarf, and dwarf will equally often meet a dwarf or a tall, and the combination will thus be in the ratio

1 TT, 1 TD, 1 DT, 1 DD

On further breeding the dwarf plants derived proved to breed true, while the tall ones included one third pure and two third hybrid, giving the proportion of 3 to 1 again.

Mendel's principles can be applied to more complicated crosses between parents differing in more than one pair of contrasting characters. In the hybrid only the dominant characters of each pair will appear. Thus the result of crossing a tall yellow-seeded pea with a dwarf green-seeded pea is a tall and yellow-seeded pea. In this hybrid there will be equal number of sex-cells, male and female, carrying the dominant and recessive factors, while the factors for each pair are sorted among them independently of each other. Hence sperms and eggs will be of four types, carrying factors as follows:—Tall yellow seeded, tall green-seeded, Dwarf yellow-seeded, Dwarf green-seeded If these hybrid forms are crossed, out of every sixteen individuals on the average, nine will show both dominants (tall, yellow), three will show the dominant of one pair and the recessive of the other (tall, green), three will show the other dominant and the other recessive (yellow, dwarf), and one will show both recessives (dwarf, green). This is called the 9: 3: 3: 1 ratio. The important point to be noted is that the characters of the parent have been recombined to give two new types, tall green-seeded and dwarf yellow-seeded. Indeed all the possible combinations of the parents' characters with respect to height and seed colour appear. This means that when several characters are considered a great variety of new forms will be produced. Some will breed true, and from others pure-breeding strains can be isolated by continually self-pollinating them.

Hence instead of looking at the individual as a whole (sum total of the whole of the characters), which is in some vague way endowed with an individuality, marking it off from its fellows, we now regard it as an organism built up of definite individual characters.

Mendel's Laws :

1. **Law of Segregation of Germinal units :—"That of a pair of contrasted characters, only one can be represented in a single gamete".** Black pig × white individual–offsprings are all black (no matter which parent is black and which white). The character of white disappears in the first generation, but reappears unchanged in the second generation, when hybrids are crossed among themselves.

2. **Law of independent assortment of Germinal Units:—"That each one of a pair of contrasted characters may be combined with either of another pair".** The entire genetic constitution of an individual, both expressed and latent, makes up its *genotype* (TD of F_1), and its appearance or the assemblage of characters, that are expressed or evident, constitutes its *phenotype* (Tall phenotype F_1)—Cf. Dihybrid.

Monohybrid :

PARENTS			F_1 GENERATION		
Phenotypes	*Genotypes*	*Gametes*	*Pheno*	*Geno*	*Gametes*
Tall	TT	T	Black	TD	T D × D T
Dwarf	DD	D		TD	

F_2 GENERATION

Pheno type	*Geno type*	*Gametes*
3 Tall	1 TT	All 'T'......Pure
	2 TD	Some 'T', some 'D'-Hybrids all tall
1 Dwarf	1 DD	All 'D'......Pure

The two genotypes (2 TD) of F_2 generation behave like the genotypes of F_1 generation, i.e. T may combine with T or with D, producing either TT or TD; similarly D may combine with T or with D, producing either DT or DD. Once again there are three genotypes produced—1 TT, 2 TD, and 1 DD.

Dihybrids :

Mendel solved the problem of dihybrids by crossing wrinkled-green peas with smooth-yellow peas. The gametes produced by the two were 'w g' and 'S Y', and the hybrid resulting from their cross was of the genotype 'S w Y g'. When the determiners of these hybrids segregate out during the maturation of their germ-cells, they may recombine so as to form four possible double gametes :

SY, Sg, wY, wg.

Of these the first and the last are exactly like the gametes produced by the grand-parents.

According to the second law of Mendel, stated above, the gene 'S' may combine with either the gene 'Y' or the gene 'g', and similarly the gene 'w' with either 'Y' or with 'g'. When these four different kinds of gametes of both sexes of the hybrids recombine, there are nine different combinations of germinal characters or nine different genotypes, but the phenotypes are only four :

		Male gametes			
		Sg	wY	SY	wg
Female gametes	Sg	Sg Sg	wY Sg	SY Sg	wg Sg
	wY	Sg wY	wY wY	SY wY	wg wY
	SY	Sg SY	wY SY	SY SY	wg SY
	wg	Sg wg	wY wg	SY wg	wg wg

There are thus sixteen plants out of which the character of smoothness is dominant in twelve, the remaining four are wrinkled. Out of the twelve smooth nine are yellow and the other three are green; whereas out of the four wrinkled three are yellow and only one is green. In all these the same ratio of three of one to only one of the other can be seen to hold good. The F_2 generation, arising from the cross of hybrids, consists of four phenotypes—9SY, 3 Sg, 3 wY, 1 wg. The nine genotypes are—SgSg, 4 SgwY, 2 SgSy, 2 Sgwg, wYwY, 2 wYSY, 2 wYSg, SYSY, wgwg.

The essential feature of Mendel's laws is mainly this: *Hereditary characters are usually independent units which segregate out upon crossing, regardless of temporary dominance.* The homozygous offsprings when mated with others of like constitution breed true to the character in question, irrespective of their ancestry.

Of the three fundamental principles underlying Mendel's law (independent unit characters, dominance and segregation). the principle of dominance has been found to hold true in a surprising number of cases, and in relation to very diverse organisms.

The excerpts from Mendel's paper contain the essential ideas (enunciated long before Weismann's theory of determinants, which has already been studied), first, that the characteristics of the individual are due to some kind of entities, "factors" or "determinants", existing in the germ-cells from which the individual is developed; second, that these factors are distributed in the germ-cells according to the laws of chance; third, that opposite factors, meeting in a germ-cell, would not blend, but segregate; and fourth, that when opposite factors meet, one tends to be dominant and the other recessive.

Variation and Evolution :

Only in a few generations of properly directed crosses there can be obtained combination of characters united in one strain, that formerly were never obtained at all or were only hit upon by the merest chance at long intervals. Herein lies the scientific control of heredity which the trinity of Mendelian principles has placed in human hands.

Where the homozygous and the heterozygous conditions are indistinguishable in appearance, the number of possible forms is 2 raised to the power of the number of factors concerned :

It one factor is concerned there are $2^1 = 2$ possible forms;
If 10 factors are concerned there are $2^{10} = 1024$ possible forms, differing from one another in at least one and at most ten characters. Where the factors interact upon one another, this number will be considerably increased.

The presence or absence of a comparatively small number of factors in a species thus carries with it the possibility of an enormous range of individual variation.

Evolution only comes about through the revival of certain variations and the elimination of others; but to be of any moment in evolutionary change, a variation must be inherited, and to be inherited it must be represented in the gametes. The new variations (addition or removal of the factor upon which the new variation owes its existence) comes into being by a sudden step and not by a process of gradual and almost imperceptible augmentation.

Practical application of Mendelian principles :

The Mendelian ideas have led to striking results in the raising of new and more profitable varieties. An excellent example is afforded by Professor Biffen's experiments : English wheat compare favourably with foreign wheat in respect of their cropping power, but have two serious defects :—*They are liable to suffer from attacks of rust and they do not bake into a good loaf.* This last property depends upon the amount of gluten present, and it is the greater proportion of this in foreign wheat It was held for some time that such wheat could not be grown in the English climate. Professor Biffen managed to obtain a hard wheat that kept its qualities when grown in England, but its cropping capacity was too low. Among the many varieties collected and grown, he managed to find one which was completely immune to rust, and as a result of an elaborate series of investigations, he was able to show that the qualities of heavy-cropping capacity, hardness of grain and immunity to rust can also be expressed in terms of Mendelian factors. Thus he was able to build up a strain of wheat which combined all these qualities.

Probably no man has made more successful use of the processes of hybridization in the production of new and valuable forms of plant life than Luther Burbank at his celebrated Californian nurseries. He produced many wonderful hybrids — white black-berries, stoneless prunes, plum-cots, and thornless cacti, are only some amongst the many novelties which he produced. We now know that such cereals as wheat and barley obey the Mendelian laws of hybridization as regards various important characters, and so also do horses as regards the colour of their coats, and human-beings as regards the colour of their eyes and in some other respects, specially the inheritance of certain diseases.

It therefore appears certain that mendelian principles have a very general application and the economic value of the knowledge of such principles is enormous.

CHAPTER X

MIMICRY

Of all devices adopted by nature for the protection of her children, none is so marvellous as those which are included under the head of mimicry—the resemblance which organisms bear to others and to inanimate objects in form, colour, shape, size, appearance, attitude, and action, thereby escaping observation or advertising an apparent harmfulness which is not at all real. The type of colouration which aids in concealment of an animal is termed by Professor Poulton as "Cryptic", as a means of escape from enemies or for the purposes of ambuscading prey, or possibly for both—thus mimicry has been classified into (a) *Protective* and (b) *Aggressive mimicry.*

Protective Mimicry or Mimesis :

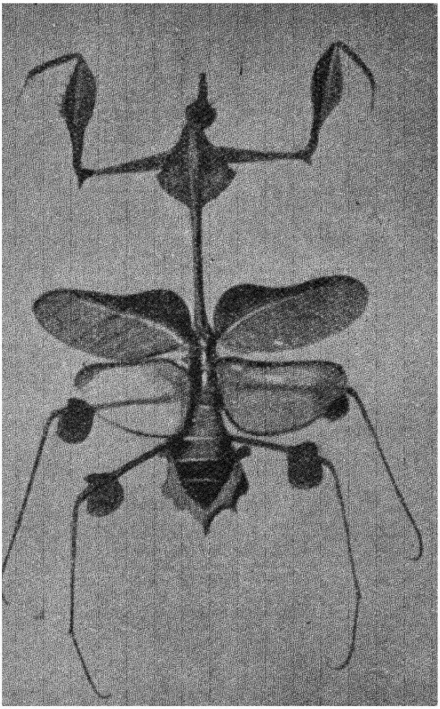
Colouration for the purpose of concealment is apparent every where. The Arctic fox, mountain horse and ptarmigan put off their grey and russet with the close of summer and gradually assume coats that blend with a world under snow. Very striking too are the heather mixture dresses of various heath and shore birds Not only are the feathers so mottled as to blend perfectly with moor-land and pebble ridge, but even the eggs are similarly tinted, so much so as often to defy detection by the keenest eyes.

The responses shown by certain common flat-fishes, such as the sole and dab, are very different. If made to swim from a sandy floor, where they are invisible, on to an area marked in geometric patches of black and white, the fishes become with the surroundings in a few minutes.

The python in the jungle might well pass for a lichen-encrusted sunlight-flecked tree branch. Sea slags counterfeit the anemones on which they feed. Anemones mimic gravel beds and Coral lines.

The essence of all such camouflage dresses is to make their wearers look like something else. A leaf butterfly even shows holes and mould spots on its wings, which in shape perfectly counterfeit leaves even to the stalk.

Stick-insects perfectly suggest dead twigs in their every feature. Some few insects like the 'orchid spiders' and mantids counterfeit flowers, less to evade enemies than to lure insects within reach.

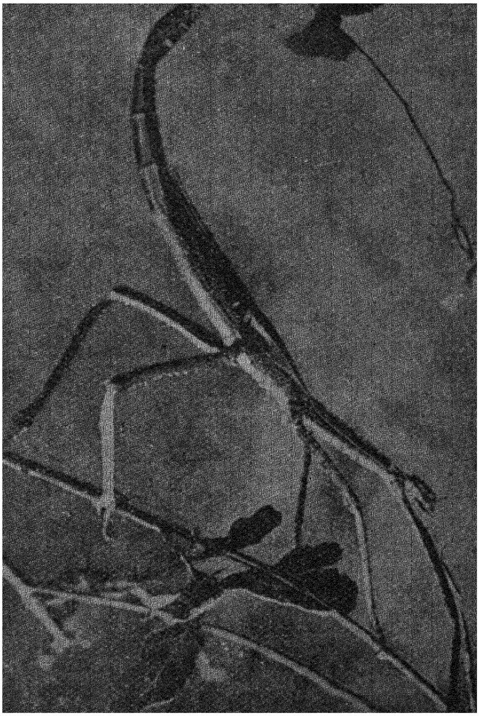


POSES AS A FLOWER
Gongylus gongyloides is coloured to resemble a flower.

The crab, *cryptolithodes*, has smooth rounded form and texture, and white colour—these harmonize very perfectly with the white quartz pebbles of the beach. The little green tree-frog can blend with its surroundings to a certain extent and so can many lizards. The chamelion has earned world fame as a quick change artist.

The geometer moth caterpillars move about with looping action amongst the leaves or branches of the bushes, but when at rest they stiffen themselves up and stand out from the branch at the exact angle of a twig.

In striking contrast with the cryptic colouration in which-self advertisement appears to be the main object in view, the noxious species advertise their true character by *signalling colours*, exhibiting that they possess special means of defence, unpleasant taste, foul smell, and the toxic nature of the animal to the enemy etc, so that they may be let alone. But it is no less advantageous for innocuous species to advertise a false character and gain credit for some power of making themselves objectionable, which they do not actually possess. The practice of bluffing is by no means an exclusively human institution.

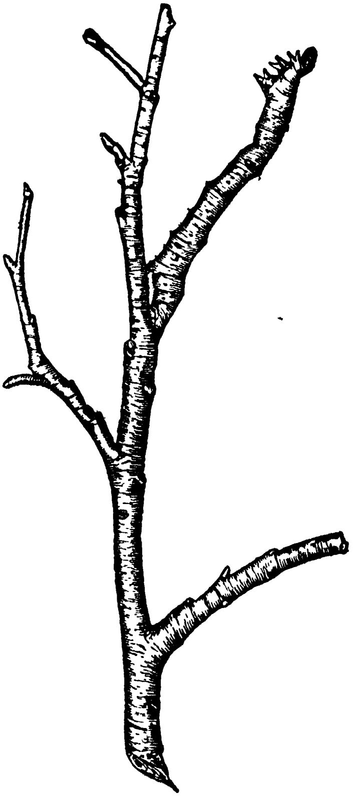


STICK INSECT
This insect is so long and thin that it looks like the branch on which it rests.

Some of the most remarkable mimicry of all is included under *warning mimicry*—mimicry of advertising coloured forms which are distasteful or even poisonous. Natural selection has achieved such most effective and subtlest of camouflages, the disguising of a harmless as a harmful species. Such a piece of bluff may be seen in the common hoverfly which many birds mistake at first glance for a wasp. There are certain poisonous snakes that are brilliantly coloured and some have alternating bands of red and black on their skins (Coral snakes). Each of these species is mimicked by other species of harmless snakes. The hairy brilliantly coloured syrphus—or flowerflies, resemble the stinging bees and wasps in their form, colour, and action.

The clear wing moths simulate bees and hornets and the American viceroy butterfly, itself tasteful to birds, imitates the nauseous monarch butterfly inhabiting the same region.

All these cases of various controversies of resemblances are usually either for concealment to defy detection, or for deception to allure prey, or for warning to ensure untouchableness—'*Hands off*' says the wasps' gaudy attire of black and gold. Yellow is a very prevalent warning colour. The skunk walks about clearly labelled as untouchable.



Geometrid larva on a branch. The twig-mimicking caterpillar is the upper right-hand projection from the stem. (From Jordan and Kellogg's *Animal Life.* [D. Appleton and Co.])

Protective mimicry has been defined as an advantageous superficial resemblance of a palatable defenceless form to another that is specially defended, so as to be disliked or feared by the majority of enemies of the groups to which both mimic and the model belong—a resemblance which appeals to the senses of enemies of sight, sometimes hearing, and rarely smell, but does not extend to deep-seated characters, except when the superficial likeness is affected thereby.

Still other animals assume a terrifying appearance which is also cent per cent bluff. The defenceless animal makes no attempt to hide from the enemy—it advertises its presence instead. It takes up such an attitude or assumes such an unusual appearance that the enemy is partly confused, partly surprised, and partly frightened, and desists from attacking. The rapid flushing of changeful colour, the raising of its head and the assumption of an attacking attitude when excited or teased, in the chameleon is well known It is a quick-change artist. Some green-coloured grasshoppers, when surprised by an enemy, spread their wings and suddenly expose red spots from the under-wings, producing a whirring noise simultaneously—all this confuses the enemy that was about to snap at the grasshopper, and it hesitates. The grasshopper, in the meantime, jumps off before the enemy has had occasion to snap it.

Mimicry is thus "sailing under false colours". Such imitation by a harmless species of a protected one is known as *Batesian Mimicry* (it was first elucidated by the English Naturalist Bates). Then came the extension of the principle by Dr. Fritz Muller, a German Naturalist, to the cases of species of distinct genera of the inedible butterflies resembling each other quite as closely as in the case of edible butterflies exhibiting warning colouration. They serve mutual advantage from becoming, in appearance, one species. The chances are that an in-experienced insectivorous bird catches one or two specimens of one species, finds them unsuitable, and in future avoids all that look alike. The effect is that the mortality of any one species is proportionately less when the bird is learning to avoid them—this kind of adaptation is known as *Mullerian Mimicry,* as different from Batesian. Another extension of the same principle explains the grouping of allied species of the same genera of inedible butterflies into sets, each having a distinct type of colouration, and each consisting of a number of species which can hardly be distinguishable on the wing. This must be useful exactly in the same way as in the last case, since it divides the inevitable toll to insectivorous birds and other animals among a number of species.

Origin and Cause of Mimetic resemblance :

In attempting to arrive at a decision upon the origin and cause of mimetic resemblance we have no direct evidence to assist us. There are, however, various theories advanced to explain them :

1. *Theory of Natural selection:* assumes that these resemblances have been produced because they are or have been useful in the struggle for existence. There has been a greater average survival in successive generations of the forms in which these useful likenesses were more stongly developed as compared with those in which they were less strongly developed, and thus in process of time a very high degree of resemblance has been attained.

2. *Theory of External causes:* assumes that mimicry has been produced by the direct action upon the organism of some one or more of the various influences which exist in the locality such as food, moisture, dryness, cold or heat.

3. *Theory of internal causes:* assumes that the resemblances are due to the independent arrival of the different species at the same evolutionary stage, as regards the character in which such resemblances are manifest.

Theory of sexual selection : has occasionally been invoked to account for mimicry—the assumption being that the selection of mates has been influenced by the colours and patterns of other species living in the same country. It is, however, manifestly absurd to attempt to account for all the various mimetic resemblances by an appeal to the operation of external or internal causes or of sexual selection. Natural selection alone offers a convincing interpretation. Under any other theory, except natural selection, the facts are gratuitous and devoid of meaning. The tendency of mimetic appearance to appear in the female rather than the male is an admitted fact of wide application. The non-mimetic males maintain the ancestral appearance which has been lost in the mimetic females. This striking exception is quite unintelligible except under the theory of natural selection, which offers the convincing explanation long ago suggested by Alfred Russell Wallace: "that the slower flight of the heavier females and their exposure to attack during oviposition render it specially advantageous for them to resemble conspicuous distasteful species in the same locality."

COLOURS

Classification:—

<table>
<tr><td colspan="4">1. Apatetic
Resembling some part of the environment or the appearance of another species.</td><td colspan="2">2. Sematic
Warning and signalling.</td><td>3. Epigamic
Displayed in courtship</td></tr>
<tr><td colspan="2">(a) Cryptic:
Protective and Aggressive Mimicry.</td><td colspan="2">(b) Pseudo-Semetic:
False Warning and Signalling</td><td colspan="2">Sematic</td><td></td></tr>
<tr><td>Procryptic
Protective.</td><td>Anticryptic
Aggressive.</td><td>Pseudo-apisematic
Protective mimicy.</td><td>Pseudo-episematic
Aggressive mimicry and alluring colouration</td><td>Aporsematic
Warning colour</td><td>Episematic
Recognition markings</td><td></td></tr>
</table>

CHAPTER XI

INHERITANCE OF ACQUIRED CHARACTERS

Inheritance of acquired characters is much more than a technical problem for biologists: That the personal accumulations of a life time are heritable was generally believed all through the credulous ages. *Aristotle* had referred to the transmission of the exact shape of a Cautery mark, although the Editor of Aristotle's '*Historia Animalium*' insinuated a doubt as to credibility of instances of this sort.

In the modern times *Kant* was one of the first to express a firm disbelief in the transmission of individual peculiarities, and *Bluemanback* was also inclined to the same opinion, but neither seems to have defined precisely what he intended to exclude from the bundle of inheritance.

Lamarck made the idea of the inheritance of acquired characters the corner stone of his theory of evolution. The reason evolution occurs in nature is because individual acquirements are being continually added to the on-flowing stream of living forms. He maintained the transmissibility of modification due to increased, decreased and changed use, and also of modification due to environ mental change, whether induced directly or indirectly induced by altered function. He has made a reference to (i) the enlongated neck and forelimbs of giraffe due to continuous stretching for many generations (ii) webbed feet of swimming birds (iii) elongated legs and beaks of wading birds due to their efforts in this direction (iv) small eyes of moles because they had ceased to use them (v) elongation of the body accompanied by the loss of limbs in snakes because of their habit of creeping between narrow holes and crevices for which limbs were decidedly a handicap and positive check in forward progression, and numerous other examples of the sort.

Lamarck propounded the theory that the characters acquired by heredity were continually passed on, yet tended to change with changes in the mode of life of the individual. Thus the whale had apparently parted with its hind legs, much as the spider-monkey had parted with its thumb, from disuse. Every succeeding whale, though sprung originally from terrestrial stock, used what hind legs it had less and less. So these gradually atrophied and shrank; until whales were born with no hind legs at all. The law apparently holds good even for accidental characters—a cat or a man, chancing to be born with six toes, would be likely to beget progeny some or all of which might present the same superfluity.

Darwin also believed in the inheritance of acquired characters, although he differed from Lamarck with respect to how such characters are acquired.

As an example of environmental effects in plants mention has been made of a wayside weed '*capsella*' which gradually crept along the road-sides up into the Alpine habitat, and there acquired Alpine characters. Upon being transplated to the lowlands it retained Alpine modifications.

There are a number of instances of the transmission of diseases:

Exophthalmia in animals born of parents in which an injury to the restiform body had produced that protrusion of the eyeball. It continued for four generations as observed by Brown-Seguard.

Haematoma and dry *Gangrene* of the ears in animals born of parents in which these ear alterations had been caused by an injury to the restiform body near the nib of the calamus.

Appearance of the various morbid states of the skin and hair of neck and face, in animals born of parents having had similar alterations in the same parts as effects of an injury to the sciatic nerve. Still another instance is of gradual acclimatization of the mould 'penicillium' to a salt solution of density sufficient to cause its death if placed in it atonce. Resulting spores of such acclimatized mould have produced moulds that are able to survive in the concentrated solution. There are however other naturalists who have doubted the transmission of acquired characters :

James Cowles Prichard (1786) drew a clear distinction between acquired and unborn peculiarities, and argued that the former were not transmitted.

Galton (1875) stated his opinion that acquired modifications are barely, it at all, inherited in the correct sense of that word.

August Weismann focussed the growing doubt about such belief in a masterly manner, and made the issue very clear. He denied all transmission of acquired modifications. In his view the sole fountain of specific change is in the germ-plasm of the sex cells. The environment does make a dint upon the organism, but only upon its 'body or soma'; the reproductive cells, through which alone the change could be transmitted, are either unaffected or are not affected in such a definite way as to bring about the transmission of the parental modifications.

Weismann defined acquired characters as those that result from external influence upon the organism, in contrast to such as spring from the construction of the germ. His original position is indicated by the following :

1. 'Characters can only be inherited in so far as their rudiments are already given in the germplasm'.

2. 'Modification that are wrought upon the formed body, in consequence of external influences, must remain limited to the organism in which they arose.'

3. 'So must it be with mutiliations and the results of use or disuse of parts of the body'.

4. 'No such modifications of the body or soma can be transmitted to the germ-cells from which the next generations springs They are, therefore, of no account in the transformation of the species'.

Numerous examples have been brought forward to support the non-inheritance of acquired characters :

1. Boring of ears and nostrils has been continued from centuries amongst human beings, but there is a complete development of these organs in the young.

2. China females wear iron shoes which cause their feet to be reduced to a short size, but the young have the same normal feet when born.

3. English ladies have got the practice of tightening up their waist which has the same normal development if allowed to develop without any tightening.

4. On cutting off the tails of a number of mice at birth, and allowing them to breed and dealing with the offsprings in the same way, a progeny of 900 was produced in six or seven generations from a single pair, and there was no diminution in the size of the tail in any one of them.

In as much as the only possible connection between parents and offspring is through the germ-cells, it follows that there must be something in these germ-cells which represents all the inheritable characters of the parents and is capable of giving rise to a repetition of these characters in the course of individual development.

It seems that there are only two possible ways in which this marvellous fact can be explained :

1. The whole of the somatic cells may be so intimately connected with the germ-cells that each of the latter bear within itself the influence of the whole of the former—an influence too of such a nature as to lead to the re-appearance of the corresponding somatic cell in the

course of development—clearly therefore an influence of a material nature.

2. We may look upon the germ-cells as directly developed from the germ-cell from which the parent arose. Parent and offspring would then resemble each other.

The first theory was suggested by Darwin under the name of "Pangenesis." It certainly explains a great deal, but it involved so many improbable assumptions that it cannot be accepted as more than what Darwin himself termed it "a *provisional hypothesis or speculation.*"

According to the second theory offspring and parent can only resemble each other in characters which were predetermined in the germ-cell from which the parent arose—this is Weismanns' theory of heredity based upon what he terms the "*Continuity of the germplasm.*" He identified the chromatin of the nucleus as the actual hereditary substance—the bearer of all inherited tendencies—and draws a very sharp distinction between the somatic cells and the germ-cells. What is exactly continuous from one generation to another is the germplasm of the germ-cells, which is thus immortal, and with this is connected the celebrated denial of inheritance of acquired characters.

The word '*continuity*' is employed to express the theory that heredity depends upon the fact that a minute quantity of the germplasm is reserved unchanged during the development of the individual, and subsequently grows and gives rise to the germ-cells. Thus the germplasm is continuous from one generation to another in unending succession, and from it the germ-cells of each generation are produced. The splitting up of the substance of the ovum into a somatic part and a propagative part, the latter reaching the germ-cell and there remaining inactive, and later giving rise to the succeeding generation, constitutes *the theory of the continuity of the germplasm.* The mass of germplasm, not retained unaltered to provide for the generative cells, is supposed to be employed in the elaboration of the individual body. The nuclear divisions are '*differentiating*' or heterogenous from the very start—the germ-cells are similar to the fertilized ovum which started development; they are in fact a piece of it, which has grown without undergoing any essential alteration.

If, however, some of the somatic cells become modified from that nature which was predetermined in the germ-plasm of the ovum, there is no way in which the hereditary transmission of such modifications can be explained.

There is, however, little to be gained by the citation of opinions, for there are equally authoritative names on both sides. The scepticism as to the inheritance or acquired characters is not a modern fad. While majority of zoologists disbelieve in mo lification-inheritance, the reverse seems to be the case with botanists.

Habit of a plant and even its structure are largely determined by the condition under which it grows. Peach trees acquired evergreen habit, and this character is hereditarily transmitted. Cherries are deciduous in England, but in Ceylon they are perennial. Chestnut has become perennial in America. Pea plants grow in winter on plains, but they do so conveniently in summer on the hills.

It cannot be an easy question when we find Spencer on one side and Weismann on the other (Herbert Spencer—"close contemplation of the facts impresses one more thoroughly than ever with the two alternatives - either there has been inheritance of acquired characters of there has been no evolution)"; Haeckel on one side and Ray Lankester on the other (Haeckel—"belief in the inheritance of acquired characters is a necessary axiom of the monistic creed. It would be better to accept a mysterious creation of all species rather than agree with Weismann"); Turner on one side and His on the other (W. Turner—"to reject such an inheritance is like looking at an object with only a single eye"), and so on.

The affirmative position is very widely held because even in regard to our own muscular and nervous systems we are familiar with illustrations of the fact that practice increases capacity and that desitude is apt to be followed by loss of power. We are also aware that changes in environment or condition of life, and notably in our food, cause changes in our body. Besides, the affirmative is an interpretation which seems to make the theory of organic evolution simpler—it suggests a more direct and rapid method than the Natural selection of germinal variations.

Moreover, many fictitious cases of the inheritance of acquired characters continue circulating, and besides such fictitious cases there are some puzzling phenomenon which the supporters of the negative position are wont to dismiss as "coincidences," which it must be confessed is never a very satisfactory way of dealing with difficult cases.

CHAPTER XII

RECAPITULATION HYPOTHESIS

Every multicellular animal or plant commences its individual life as a unicellular egg or ovum, and gradually passes, by slow stages of cell division and differentiation, into the adult condition. There are of course apparent exceptions to this rule in those cases that reproduce by budding or by some other analogous process. But even in these cases reproduction by means of germ-cells is resorted to at more or less frequent intervals, and the budding must be regarded merely as an additional method of multiplication interpolated in the life-cycle. The individual organism then does not come into being fully formed in all its perfection, but passes through a longer or shorter process of development to the adult condition. In fact it undergoes a process of individual evolution, which constitutes its individual life-history or *Ontogeny*. This fact is also very significant from the point of view of the evolutionist. An individual sometimes passes through stages which may be compared with the free living adults of some of the lower forms.

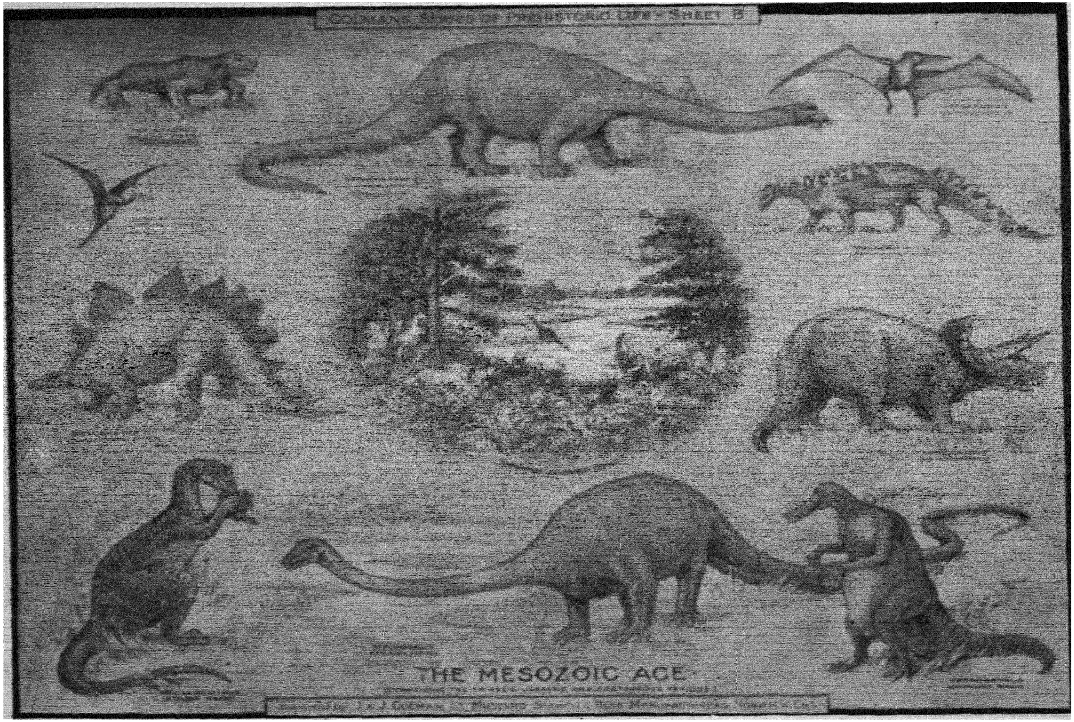
If a series of embryos, belonging to different vertebrate types, are examined and their life-histories traced backward, it is found that they gradually converge, and the different embryos come to resemble one another so closely that even an experienced embryologist could hardly distinguish between them. In its earliest stage every organism has a great number of characters in common with other organisms in their earliest stages; and at each successive stage the series of embryos which it resembles is narrowed. Progress in development is from a general to a special type. The embryos of the closely allied forms resemble each other for a long time, and it is at a very late period in their development that they are demarcated. Thus if we compare the embryos of a gorilla, chimpanzee, apeman, and man himself, we will notice that the resemblance is so great that it is extremely difficult to tell which is which.

This great generalization of Von-Baer (1827) contained the germ of what is now known as the *Recapitulation hypothesis* or as Hæckel has termed it "the *Biogenetic Law*" which states that every organism, in its individual life history, repeats the various stages of growth through which its ancestors have passed in the course of their evolution. In other words "*Ontogeny or life history of the individual is a repetition of Phylogeny or the ancestral history of the race to which the individual belongs.*" Or, to make the matter still more simple, every individual is a "historic document".

Embryologists have made the fact most vivid that individual animal develops along a path the stations of which correspond to some extent with the steps of ancestral history.

Interpretation of stages in frog in accordance with recapitulation theory :

1. The unicellular ovum	1. Remote protozoon ancestors common to the whole animal kingdom.
2. Segmentation of ovum into primitive embryonic cells or blastomeres	2. Transition from the condition of the simple protozoon to that of the protozoon colony (individual cells remain together without any marked differentiation.
3. The process of gastrulation, with primitive digestive cavity and primitive mouth	3 Transition from protozoon colony to the Coelenterate stage of evolution (still represented by such forms


PREHISTORIC LIFE – SHEET 8
THE MESOZOIC AGE

most prominent of early reptilian orders which was destined to give rise to Mammals—long-snouted, semi-aquatic fish-eaters; others with long spines and crossbars. Dimetrodon and Haptodus were the dominant carnivores of Permian from which the later Therapsids appear to have been derived. There is however no evidence of Sauropsidian reptiles which were to become prominent in the Mesozoic.

At the end of the Palaeozoic era our-story is broken in the middle of the sentence.

The Mesozoic era is usually known as the "Age of Reptiles". There flourished the great reptilian groups now extinct: (i) the varied Dinosaurs on land—they attained an enormous size—many of them weighed as much as a large locomotive, yet their brains were smaller than that of a nine pound human infant—Iguanodon, 30 feet long; stegosaurus, the plated-lizard; Diplodocus eightly feet long; Brontosaurus, fifty-five feet long; the flying reptiles, Pterodactyles and Pterosaurs in the air—some were as small as a house-sparrow, others had a wing span of as much as twenty four feet, and (iii) Icthyosaurs and Plesiosaurs and other marine types, exceeding seventy five feet in length, in the seas—all these were real dragons though they did not breathe fire as the legend says. They ruled in horror, but the future did not lie with them as there was not a brain worthy of the name among them.

It also witnessed the modest beginning of existing reptile groups—turtles, lizards, snakes, and crocodiles. The first true birds appear in this era. The oldest bird known, *Archaeopteryx,* was about the size of a crow. This era also marked the first appearance of mammals. The early mammals were all small, no larger than breeds of modern dogs. They were the descendants of a group of reptiles that lived during the last days of the Palaeozoic era.

In the Cenozoic era there were tremendous up-heavals of the sea, and most of the great modern mountain chains were made. Not only were cretaceous deposits raised into lowlands, but "from the Pyrennes to Japan the bed of the early tertiary sea was up-heaved into a succession of giant mountains; some portions of that seashore now standing at a height of atleast 16,500 feet above the sea." Almost the whole of the gigantic race of reptiles died out; and it is now an age of big mammals. Not only have the monstrous reptiles died out but all animals, large and small, have changed, and have come much more to resemble the animals of modern times. Still, however, monsters that have not survived to present days continue to be produced—mastodons, mammoths, sabre-toothed tigers, and tortoises six feet long.

Among the *Quarternary* rocks we find the oldest traces of man. During this period, too, occurred the Great Ice Age. In the Pleistocene period we find not only evidences of tremendous glaciation, but of the predominance of animal forms well fitted to survive under conditions of intense cold. It was a time of wholesale extinctions, when many races of animals were blotted out; but mankind, because of his superior mental attributes, was able to survive, and rapidly took his place as the dominant form of life.

With the final retreat of ice the Psychozoic era or Age of Man began with the greater perfection of man's mentality and the rise of world civilization.

Armour and size were the order for reptiles, size and weapons for the mammals; herb-eaters grew gigantic; flesh-eaters grew huge. Nature, though she explored possibilities with every order, though she sent the whole back from land and let them grow monstrous in the sea, has ceased its striving for giants.

CAPTER XIV

FOSSILS AND HOW THEY ARE FORMED

Fossils are organic remains of plants and animals, preserved in rocks, or imprints of organic bodies in rocks- Fossils may be of all kinds and sizes: the skeleton of the mammoth with hair and flesh still adhering, the track of a worm marked on sandstone or shale, the sharks' teeth in the deep-sea ooze, are all fossils.

The stratified rocks laid down in prehistoric lakes, rivers, seas and oceans, contain so many fossils of creatures which, from their very nature, must have been dwellers upon the land; when they died their bones were carried by running water to sea and deposited there amid the debris brought down by prehistoric rivers; they may have been suddenly overwhelmed in vast floods and beneath tons of sediment, or they might have been bogged in marshes and swamps and died there, to leave their bones embedded in mud, which ages after became hard rock under pressure of the millions of tons of sediment which accumulated above it.

Every organism, thus, in order that it might be preserved and subsequently discovered as a fossil, must fulfil the following conditions : It must find its way into water where sediment is being deposited, and there escape all the dangers of being eaten up, or it must be accidentally entombed in blown sand or a valcanic accumulation on land.

This sediment, if it eventually happens to enter into the composition of land area, must escape the all prevalent denundation or destruction and removal by atmospheric and aqueous agencies-decompositions are otherwise continually in progress.

The skeleton of the buried organism must resist the solvent action of any water that may percolat ethrough the rock, and finally man must accidentally excavate at the precise spot where entombment took place.

But perhaps the greatest cause of the stratified rocks containing so many fossils was the alternate submergence and elevation of the ancient land surfaces which occurred over and over again in prehistoric times. Sometimes these changes were gradual and prolonged; sometimes they were sudden and cataclysmic.

CHAPTER XV

CONDITION IN WHICH FOSSILS OCCUR.

A Fossil may only be a foot print or a leaf-impression, a cast of a shell, a nut, or a bone; actual bony structure or the actual shell—it is only the hard parts of organisms that leave traces or form fossils.

The entire Organism might be preserved: although in most cases undergone radical changes under exceptionally favourable conditions the soft parts as well as skeletons have been preserved—woolly Rhinoceros and Mammoth are so perfectly preserved in ice, sixty miles north of arctic circle in Siberia, that of some the flesh was eaten after many thousand years it was accidentally placed there in cold storage. Insects and plants are encased in fossil resin known as amber—skin, hair, and dung of ground-sloths in Navada Caves.

The skeleton may be preserved almost unchanged : it loses only organic matter and is preserved in its original condition—Skeletons of giant elk and other animals in peat bogs in Ireland and elsewhere; and skeletons of many species trapped in asphalt pits or "Tar-pools" of Southern California.

A part only of the skeleton may be preserved : it might be argued that a part of the skeleton cannot give us any idea of the organism to which it belongs; but we have to reckon the principle of "Co-relation of parts" first applied by the eminent French Palaeontologist 'Cuvier' in 1852, according to which all parts of an organism stand in certain fixed relationship to one another so that one part cannot vary without a corresponding variation taking place in another. It is said of Cuvier that he rarely failed in naming an animal from only a part of its skeleton, and that he could reconstruct the form, habits, and life-conditions of a prehistoric animal by examination of its fossil form and by analogy with its nearest living representative. The elaboration of the principle is such that frequently a single bone, tooth, or plate, a sadly demolished carapace, a shell-fragment, a bit of a stem, and the like is sufficient to form a tolerably accurate conception of their former owner.

The remains might be replaced, atom for atom, by foreign matter : the result may be either—

Carbonization—this is better illustrated in the case of plants. It is deoxidizing process taking place under water or with limited access of air—coal formations. In some cases the preservation is so perfect that even the venation of the leaves is clearly discernible.

Decomposition - the process effectually destroys all organic carbon and nitrogenous compounds; even the conservable hard parts of the bodies of animals are deprived of their organic compounds—bones lose their fats and oils; and the shells of molluscs, Echinoderms and crustaceans lose their pigment and soft substance.

Petrifaction : In the compensating action of nature, chemical agents, in destroying the original structure, infiltrate the vacancy with minerals, particle by particle, replacing the form occasionally in minutest detail. Bony matter becomes altered into complex type of mineral in which much of the original constituents of the bone remain.

The organism may leave Moulds or Casts of their exterior or interior structures :

Soft parts of organisms, if embedded in a porous stratum, get decomposed, and the interior is filled with the same material as the stratum. Water, containing carbonic acid, percolates and carries the shell with it—the space, thus filled with mineral matter, forms a mould. They are left in the surrounding rock after the substance of the animal or plant has decayed and disappeared.

Or again, fossils may be *imprints* - not infrequently fossil organisms leave imprints of their shells, skeletons, foot-prints and very rarely of their whole bodies in the rocks.

Some fossil records of animal activities survive as tracks, burrows, tubes and droppings.

CHAPTER XVI

USEFULNESS OF FOSSIL STUDY

Fossils have excited man's interest from the earliest times. Among the Greeks and Romans who were in turn masters of the Ancient worlds, they gave rise to endless speculation— they are food for the intellect.

They are measures of Geologic time— When we examine the fossils thus preserved in rocks, we find that lower and higher layers contain different fossils, and that they are graded in a regular order as we ascend. We find too, that if certain fossils are found in a certain stratum, and the same fossils are also found somewhere else in another stratum of similar structure, that the latter stratum is of the same geological age as the former. It is the fossil more than the mineralogy of the rock that tells its geological age. Fossils are used for identifying rock strata and for indicating a time sequence of each strata.

Fossils show that in the past various groups of animals came to great prominence and later perished completely—each great group seems to have begun in a small way, then developed rapidly, branching out in many directions, and becoming the dominant group for the time being— only to dwindle away again and give place to some new and vigorous offshoot.

Besides their chronological value the fossils *indicate the conditions under which the formations were deposited* : if fossil remains of land animals and plants are associated with marine species, it is indicative of shallow waters. Rocks of Mesozoic place before us new and wonderful life-forms, which flourished under conditions entirely different from those which characterized the Palaeozoic Era—luxuriant vegetation, growth in extraordinary profusion, and vast areas covered with jungle-huge reptiles lumbered heavily over the land. At the close of Mesozoic era they vanish utterly from the rocks—some great and sudden change brought cold and starvation to them. Fossils are thus also *indicators of past climatic conditions.*

Fossils *present great antiquity of the earth*, and they are of the greatest importance to the Biologists—Fossils include ancestors of modern species, and show the inter-relations *of bygone animals and the racial history of animals* and plants. They connect groups which seem to be quite distinct.

The modern horse has a well established family tree, extending backwards, without serious gaps, for atleast 3,000,000 years, to the four-toed ancestor Eohippus.

Fossils have therefore *a great bearing on the subject of Evolution*, and they threw a flood of light upon the living things that had once flourished upon the earth. They give an *evidence to Recapitulation Theory*, and tell us that evolution has proceeded by slow and gradual modifications. They also give us the evidence that evolution was orthogenetic—the evolutionary changes in any one group of animals proceeded in definite direction for considerable period of time—an order exhibits a large geologic time than family, its family types persist for a longer time than any of the genera, while the genera themselves remain for a more extended period than the species.

CHAPTER XVII

IMPERFECTION OF GEOLOGICAL RECORD

The difficulties in ascertaining and interpreting the facts of palaeontology are greatly enhanced by the imperfection of the geological record on which we depend.

The stress and strain set up in the earth's crust, as a result of its efforts to adapt itself as to its steadily contracting interior, brought about vast fractures and crumpling and bendings which often had the effect of bringing to the surface rocks that lay far below, and of sinking to great depths other strata much more recent in formation.

Not every rock contains fossils—Igneous rocks donot, and many stratified rocks have no fossils at all. Besides, like all great books, the *Book of the Rocks* is divided into many volumes, and each volume into many chapters. Pages are missing here and there and the reader has only to guess what they contain. The pages, however, of the great stone-book cannot be shuffled over in order to read the story contained therein, for they are firmly stuck together. The difficulty of separating and arranging strata is greatly increased by the fact that we can see only their edges and that, as a rule only a comparatively few edges are visible.

The fossil writing is quite inaccessible except as lucky chance reveals enticing fragments of it. Every item of knowledge acquired may be literally described as owing to a chapter of accidents.

Only a very small proportion of plants and animals have been preserved and those too in an imperfect manner. For every thing whose fossil has left traces of its existence, there must have been millions whose soft bodies have left not the faintest record. Our reconstruction of past life is atleast only partial.

Some animals are without hard parts. Land animals frequently do not become covered up with sediment—they have but little chance. Remains of animals, originally present in rocks, are usually dissolved by percolating water. Denundations, decompositions, destruction by atmospheric and aqueous agencies are continually in play. It is, therefore, not difficult to see how few would be the animals that can come across the necessary conditions for fossilization.

There are breaks in the succession of the sedimentary rocks, and at times there have been temporary absence of deposition. Even if there be no breaks, a difficulty in tracing out phylogeny is due to the changes taking place in the physical conditions during the deposition of a series of beds. Earlier records of fossils have been entirely obliterated by the action of heat and pressure changes in the depths of the sea, changed nature on the floor of the ocean and temperature of the water. A physical change reacts on the fauna tending to the migration of the animals to favourable conditions, and thus the descendants of animals in one stratum would not be found fossil in the overlying beds of the same area. The internal heat of the earth did play havoc and effacement, but the life on earth is one both of unbroken relation and progress— the gaps exist because the record is mutilated: *Nature, like the Sybil, has destroyed her books.*

In the seemingly sudden appearance of highly organized animals, the armoured fishes, in the Silurian rocks, marking so great an advance in structure on the higher invertebrates, the imperfection of the geological record is brought home to us. For if later forms are modified descendants of earlier, then not only are the transitional ancestral forms of the armoured fishes or ganoids missing, but the species itself is enomously older than the fossils *imply.*

Man's borings into the earth's crust, to discover fossils, are the merest scratches, and alone could reveal little as to what lay far beneath. The deepest hole that man has ever dug is in West Virginia, 7579 feet, by the Bureau of the Mines. The deepest mine is in Brazil, 6729 feet as a vertical depth. A distance of only 4000 feet below sea level represents the nearest approach man has ever made to the centre of the earth, which, compared with the total diameter of 8000 miles, sinks into mere insignificance.

David Jordan has truly said that the case of a Palaeontologist is like that of a traveller who, landing for five minutes on some remote corner of Australia, forthwith attempts a description of the entire continent. The story is far from complete, for many animals are unsuitable for producing fossils, even granted that they ended their existence in a place where fossilization was possible. The geological record must, therefore, inevitably be incomplete, for as Darwin aptly described it. " it is like a book from which many pages are torn and upon those that remain but a few words are legible."

CHAPTER XVIII

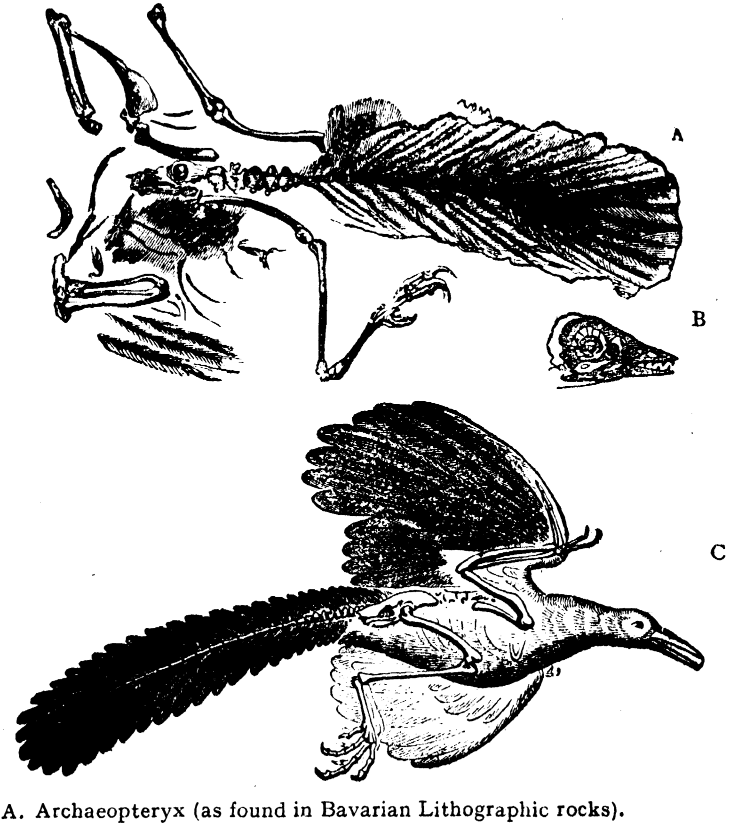
Archaeopteryx-Lithographica

The earliest birds that we know of were found as fossils in Bavarian Slate deposits that date back to the Jurassic period (approximately 140,000,000 years ago). They were named Archaeopteryx and Archaeornis. These lizard-birds were as large as pigeons and had an elongated body similar to that of a lizard.

Only two fossil specimens of archaeopteryx were discovered, and of these two one has been preserved in the British Museum, and the other in Berlin. It is only recently and in the same locality that a third specimen was excavated.

Archaeopteryx appears to have been intermediate in size between an ordinary pigeon and a crow. It does not correspond to any known past or present birds, but represents a transitional type, having both bird and reptile-like characters. The body was covered with feathers, except for the head and neck which had scales. The tail was long, made up of separate bones or prolonged vertebrae (a feature noted in the embryos of birds), and had a row of feathers down each side. Teeth were present in both jaws, and the shape of the skull was more like that of reptile than of a bird. It had grasping feet which were in no way concerned with flight, as with bats and pterodactyles. The hand or fore-limb, which apparently was used as a wing, had three long slender clawed fingers.

The bird appears to have enjoyed a moderate power of flight. The clawed digits of the manus were doubtless effective in climbing trees and rocks—they do suggest that the bird lived in forests where it climbed, jumped, and glided among the branches. It used its arms and tail for support in its soaring leaps from tree to tree or to the earth, for, while good climber, it was also well able to run on the ground (the long tail was probably used as a rudder).



A. Archaeopteryx (as found in Bavarian Lithographic rocks).
B. Skull.
C. Archaeopteryx (restored).

It has been suggested that the reptilian scales on the edges of the fore-limbs became long and loose and gradually frayed out to form feathers.

Archaeopteryx is characterized by the possession of the following characters besides several others:

Reptilian:

None of the bones appear to be pneumatic. There is a sclerotic ring in the orbit—characteristic of reptiles;

There is a series of thirteen conical teeth on each side in the upper jaw, fixed probably in distinct sockets;

In addition to cervical and thoracic ribs there were abdominal ribs like those of sphenodon and crocodiles;

The lizard-like manus terminates in three-clawed digits;

The three pelvic elements appear to have been distinct and united with each other by persistent sutures;

Acetabulum is perforated.

Avian :

The sternum is not well preserved, but the coracoids and furcula resemble those of existing birds;

Hind limb is essentially bird-like;

In the wing are observed seven primary and ten secondary remiges with their coverts;

The rectrices of the tail are arranged in pairs directed obliquely backwards—one pair to each vertebra. Archaeopteryx thus blended bird and reptile in a remarkable way, for it had a jointed tail like a lizard, teeth which no living birds possess, wing-fingers and indisputable feathers. So, unlike any bird we know today, it was all the same a bird in very fact.

Ancestry of Horse :

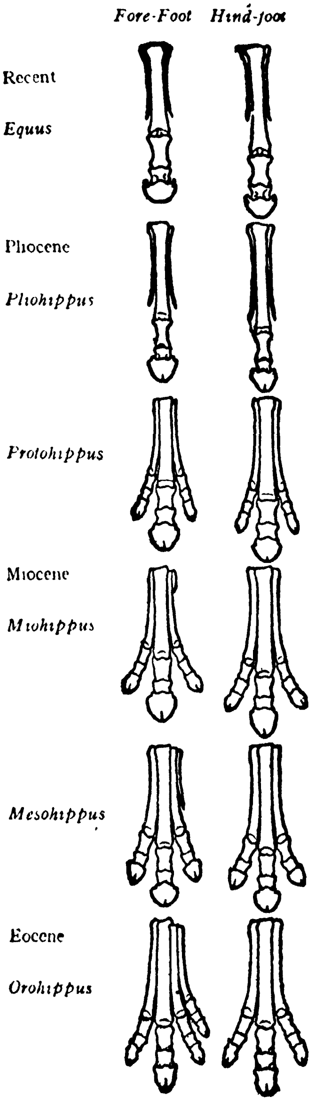
The members of the horse family or Equidae are characterized by the possession of but a single functional toe--the third toe on each foot. The second and fourth toes are represented by vestigial remnants or "splint bones". The molar teeth are highly complex in structure and wear down through most of the life of the individual. The most convincing record of the ancestry of any vertebrate is that of the horse with respect to toes, teeth, and general form. The gradual perfection of the present type may be traced back through an unbroken line of ancestors to a very generalized type with four functional toes, generalized teeth, and comparatively small size—an Eocene formation of Europe, the London clay, produced.

Hyracotherium is the most ancient known equine, while in Western North America the earliest American genus 'Eohippus' has been found. Both these genera are very much alike—the creatures were about the size of a fox, with four hoofed toes on each foot. Here, if anywhere, a demonstrative historical proof has been obtained of the truth of the doctrine of organic evolution. The forms that are utilized for the continuous series connecting the modern horse are :

Eocene :

Eohippus, the dawn horse, of the lower Eocene ranged in size from that of a cat to a fox terrier. It was averaging about 12 inches, and had short head and neck. The hand had four complete toes, each terminating in a hoof-like nail, with no trace of the first digit.

Orohippus, the mountain horse, of the middle Eocene, exhibited an advance by the loss of the splint of the fifth digit of the foot, and slight increase of size.



ANCESTORY OF HORSE
Remains of Fore and Hind limbs.

Oligocene :

Mesohippus, of the lower and middle oligocene, had attained the size of a wolf, and had three functional digits in both hand and foot—the side toes touched the ground, but the middle toe was much the largest and bore the creature's entire weight.

Miohippus, of the upper oligocene, was very similar to Mesohippus and can hardly be distinguished from it.

In all these four genera of the Eocene and oligocene the teeth were small and crowned without cement.

Parahippus, of the lower Miocene, was very much like Miohippus, but it showed valleys between the crest of the teeth beginning to be filled up with cement formed as a deposit of "tartar" on the emerging portion of the crown.

Merychippus, of the middle Miocene, is of special interest in that it marks the transition from the horse-like forms with short-crowned uncemented teeth to the true horses with long-crowned cemented molars. It was three-toed, but the side toes did not touch the ground.

Protohippus of the upper Miocene, represents a form derived from Merychippus.

Miocene :

Pliohippus of the pliocene, is closely related to protohippus, but differs from it in being one-toed horse. It was also large in size, being about forty inches at the shoulder.

Pliocene :

Plesippus, another pliocene horse, was about the size of the Arab horse but the feet were much smaller. The teeth showed an advance over those of Pliohippus, in having longer less curved crown—such as it is in Equus.

Pliocene and Pleistocene :

Equus, the modern horse, first appears in the upper pliocene and represents the culmination of the race. The feet are one-toed with splints of second and fourth.

Such a series of orderly evolutionary changes is an example of Orthogenesis. The progress shows an increase in size, diminution in the number of digits, an increased folding of the molar teeth and other differentiations.

During late Eocene times the first grasses arose and gained a foothold. These plants spread rapidly over vast areas of territory unsuitable for other plants, and offered a new energy source for any animal capable of exploiting it—this was the chief incentive back of evolution of the horses, which steadily became larger, swifter of foot and longer of neck. Their teeth became more and more specialized for grinding the harsh grass tissue. As the horses grew more numerous they became the prey of swift-footed carnivores, and speed on foot was the prime necessity for survival.

The horses began to specialize for longer legs and tiptoe running, resulting in the steady loss of their hoofed toes until the more recent horses came to possess but one functional toe on each foot, armed with a massive modified claw, the hoof.

PART III

ZOOGEOGRAPHY

CHAPTER XIX

ZOOGEOGRAPHY

It is a fact that the various species of animals are not uniformly dispersed over the surface of the earth. As we travel in any direction from our starting point we meet with new animals, some of them very much like those we leave behind us, but others altogether unlike anything we had seen before.

A science of chorology did not develop so long as man was satisfied that the earth has been arbitrarily populated by independent acts of special creation. But when man developed the conception, culminating with Darwin, that all organs are more or less related to each other, and that every species arose by modification from some other, then the manner of distribution over the earth became full of significance.

It was long thought that the manner in which the various kinds of animals are dispersed over the globe is almost wholly due to diversities of climate and vegetation- *Arctic regions* are strongly characterized by their white bears, foxes, reindeer and white owls; *the temperate zone* has its foxes, wolves, rabbits, sheep; while the *tropical regions* alone produce apes, elephants, parrots, pea-cocks, and a thousand strange quadrupeds and brilliant birds, camels and ostriches in the deserts, tapirs and deer in forests.

A more detailed and accurate knowledge of the production of different portions of the earth however showed that the differences in the fauna of the various regions are not due to differences of temperature or climate nor upon distance: there are no grizzly bears in Switzerland, no birds of paradise in California, nor snakes in Ireland, although the climate is, in each case, suitable for the absentees. The equatorial forests of South Africa and South America have practically the same climate, yet Africa is characterized by elephants, apes and leopards, while the latter has none of these animals but does support tapirs and long-tailed monkeys.

England and Japan have a good deal of resemblance in their fauna, yet a journey from England to central Africa (shorter by hundreds of miles than that to Japan) brings the traveller into contact with forms of life altogether different from those which occur in the British Isles. In the Eastern Archipelago, the two islands Bali and Lombok are separated only by a few miles, yet traversing this narrow strait produces an entire change in the fauna—an entirely new race of mammals, the Marsupials, is met with; while the Apes, Carnivora, and Ungulata entirely vanish or get exceedingly rare; but shallow straits like English channel or the strait of Malacca are not found to have the same effect—the animals are quite indentical on their opposite shores. It is thus evident that the dispersal and distribution of animals is governed by laws which are far from simple. Struggle for existence, by rapid rate of multiplication and consequent scarcity of food, renders the dispersal of animals imperative. Gradually changing climatic conditions, which render the old home no longer suitable, impel migration where migratory roads exist, otherwise gradual extinction is often the result.

A species does not necessarily occur in all places suitable for it, but only in those to which it has access, and this depends on its own past history or that of its ancestors. Animal distribution today is the joint result of existing barriers and of environmental conditions in the past. Continents have existed for long periods but have undergone many local alterations of elevation and erosion of mountain ranges, change in the existence of lakes and streams. Some were connected with 'land-bridges' and separated by seas at other periods. Warm climate extended to the polar regions in some periods, whereas glaciers blanketted much of the northern hemisphere in the Pleistocene All such changes have altered the distribution of animals.

Jordan and Kellog formulated three laws determining the distribution of animals:

Every species is found everywhere that conditions are suitable unless—

(i) *it was unable to get there*—there are no humming birds in Africa, while there are over 450 species in South and Central America, not because Africa is unfavourable to their occupation, but they could not cross the wide ocean.

(ii) *having 'got there' it was unable to stay*—U. S. Government introduced camels into the semi-arid regions of South-West, and allowed them to run wild in the hope they would multiply, spread, and eventually form a valuable addition to a region inhospitable to most large animals. The environment was congenial but the local cowboys pelted them to death.

(iii) *having 'got there' it became modified into another species :* such were the adaptable round pegs thrown into a new habitat of square holes. They remained there and squared themselves to fit the new holes. They did win out new territory at the expense of their own individuality. They were immigrants who deserted the ways of their mother-country and became naturalized in the land of their adoption.

To these three laws may be added a fourth: each species originated from some preceding species at one definite place, and its present distribution is the result of two opposing factors—*factors* of *expansion* and those of *repression.*

Expansive facilities :

These are inherent in the reproductive processes of all organisms :

A single Cod produces nine million eggs. Infant mortality must come to the rescue otherwise only within a few generations every available inch of space in the ocean will be occupied by Codfish.

Elephants, the slowest breeders, produce six young in a life-time of one hundred years. In 750 years one single pair would produce 19,000,000 descendants. If twenty feet space be allowed for each elephant, it would mean a continuous parade, reaching one and a half times around the world at the equator.

A bird produces ten pairs of young. Taking five years as average life, it will increase to 100,000,000 in forty years.

Factors inducing expansion :

(i) *Insistent need of food-* food in any one district is strictly limited and there is thus a natural tendency to roam about in search of food.

(ii) *Change of habitat* : the drying up of ditches and streams, deforestation, fire, flood, change of seasons etc – animals forsake unlivable surroundings and seek a more hospitable place—this plays a very important role in expansive distribution. The only other alternatives, under such changes, are that the animals may succumb or mark time for favourable conditions to return, or that they may be plastic.

Means of Dispersal :

Wind, water, tides and moving streams and oceans, floating icebergs, are all highways of travel. The widely distributed animals are either flying animals, independent of barriers which impede the purely terrestrial species, or possess some special facilities for voluntary or involuntary translocation from country to country.

Insects can fly long distances and their flight is considerably accelerated by winds; in some cases they attach themselves to floating timber or other floating objects and thus cross the seas. Their eggs might also be blown by the wind, or as in the case of water-beetles might attach to the claws of birds and carried from place to place. Eggs of amphibians adhere to ice-bergs and cross a great expanse of the ocean. The tenacity of life among reptiles in general and the power of swimming among lizards and snakes have all helped in their being carried to long distances. Birds are flying animals and are therefore widely distributed. In mammals, in some cases, icefloes and driftwood have aided in dispersal. Man has probably done more than any other animal in furthering the spread of organisms. In many instances it has been done intelligently, but frequently man has made tremendous mistakes.

These expansive factors are kept in control by the opposing repressive factors—thus maintaining a balance.

Factors of Repression :

The factors that hinder dispersal are :

(i) *Inadequate means of dispersa*—there are organisms whose structure is not particularly adapted to locomotion over considerable distances. Planaria gonocephala travels 0·65 m.m. in one second or one mile in one month, yet the race is not by all means always to the swift.

(ii) *Non-adaptability to new conditions*: this is a deterrant factor.

(iii) *Barriers of various kinds* : these are mainly three :

(a) *Physical* : Temperature is a wide-spread physical barrier. The cold-blooded animals are excluded from low temperature lands, affecting the distribution of amphibians and reptiles. Snakes become very scarce in temperate and cold climates and entirely cease at 620 north latitude, and they donot ascend lofty mountains, ceasing at 6,000 feet elevation.

In the ocean *pressure* acts as a barrier that stratifies the inhabitants with certain limits to which they have become specially adapted. Deep Sea-fishes cannot come to the surface, nor can pelagic forms sink far below and survive.

Humidity, according to its degree, is largely impassable to exploring organisms, depending upon a certain optimum moisture.

Light halts the traffic of nocturnal darkness-lovers.

(b) *Geographical* : these barriers are such features of the earth's crust as oceans, land-masses, rivers, mountains, waterfalls, deserts, forests, and the like.

A desert is an impassable barrier to a squirrel but not to a camel, while a forest is just the opposite. An entirely arboreal creature cannot pass across level tract of country with no trees, nor can an amphibian, whose skin requires to be kept constantly moist, cross an arid desert.

A wide expanse of the ocean is an effectual barrier to Mammals and Reptiles, but not altogether to Birds. Only a few of the mammals and reptiles can swim and that too for limited distances and they are thus seldom able to reach the land at the other end. Birds and insects have the power of flight and have a far greater dissemination than the earthworms and amphibians which are killed by sea-water, even so much so that amphibians are absent from oceanic islands.

In the great Amazonian plains many species of monkeys, birds, and even insects are found up to the river banks on one side but donot cross to the other.

Changes in climate act as barriers only to a slight degree. Man-like apes, elephants. and parrots are all exclusively dwellers of tropical or subtropical climates; while the Polar-bear and Musk ox are equally characteristic of the Arctic Zone. To a great extent this must be regarded as a comparatively modern adaptive feature, since many of these Arctic and tropical animals belong to groups the distribution of which, either in the past or present, is more or less independent of climate. Elephants for instance inhabited Siberia at a time when the climate, although probably less cold than at present, was certainly not tropical, while the Polar Bear is a specialized member of a group some of the representatives of which are denizens of the tropics.

High Mountain ranges, stretches of water, varying topographical and climatic features with correlated differences in vegetation and potential food supply, prevent the spread of purely land forms. Whereas differences in salinity, temperature, and current and tides influence the distribution of aquatic forms.

These barriers have by no means remained constant throughout geological times, for the configuration of earth's surface has been altered by susbsidences and upheavals.

(c) *Biological.* These barriers are bound up with eternal food problem. Absence of food of a particular kind prevents the advance of invading animals. Hundreds of lepidoptera can subsist in larva state only upon one species of plants; other insects require succulent vegetative food all the year round and hence they are confined to tropical regions only; some can live on waterplants, and others on mountain vegetation.

It often happens that certain parasites forbid the advance of animals : tse-tse fly transmits a fatal blood parasite to cattle, and this debars them from successful maintenance in the fertile areas of tropical Africa.

The greatest biological barrier is man.

All these barriers are of unequal importance according to the particular animal under consideration and discussion. What is an effectual barrier to one may be a highway to another.

If the factors of expansion and repression were equal, the area occupied by each species would be a perfect circle, but such a case is unknown.

The range of species, thus surrounded by barriers to the dispersal of the animal, leads to isolation, and geographical isolation protects the species and presents its archaic characters and encourages radiative adaptation.

CHAPTER XX

ZOOLOGICAL REALMS

The entire land masses have been divided into life-realms according to the distribution of animals and plants. These realms must vary according to the kind of animals inhabitants selected to serve as determinants, and do not concede with the familiar political boundaries.

The merits of initiating a natural system, that of determining Zoological realms, not by arbitrary consideration but by studying the actual ranges of the more important groups of animals, is due to Mr. Sclater who, in 1857, established six primary Zoological regions from a detailed examination of the distribution of the chief genera and families of birds. This division received great support from Dr. Gunther who, in the proceedings of the Zoological Society for 1858, showed that the Geographical distribution of reptiles agreed with it very closely. There were apparent objections to utilizing barrier-defying creatures for this purpose, and accordingly Mr. Andrew Urray, in 1866, and more in detail Alfred Russel Wallace in 1876, based their conclusions upon the distribution of mammals—these animals present the most advantages for the purpose, and are most recently evolved group. They had not much time to radiate from their centres of origin.

Wallace's Classification consists of six large regions, each divided into four sub-regions:

1. **Palaearctic Region**—divided into:
    (a) European region—including central and northern Europe, bounded on the east by the Caspian sea and Ural mountains.
    (b) *Mediterranean Sub-region* north of Africa to the tropic of Cancer.

(c) North Asia or Siberian Sub-region—all north and Central Asia.

(d) Manchurian Sub-region—consisting of Japan and North China.

2. **Nearctic Region**—divided into :

(a) Californian sub-region, consisting of California and Oregon.

(b) Rocky mountain Sub-region, consisting of the great mountain range with its plateaus, and the Central plains and prairies, and including Mexico and Texas.

(c) Alleghanian Sub-region—including the Mississippi valley, the Alleghany mountains, and the Eastern united states. This is an old forest district.

(d) Canadian Sub-region—comprises all the northern part of the continent from the great lakes to the Arctic ocean.

3. **Ethiopean Region**—divided into :

(a) East Africa

(b) West Africa

(c) South Africa

(d) Madagascar and adjacent islands.

4. **Oriental Region**—consists of all India and China from the limits of the Palaearctic region, all the Malaya-peninsula and islands as far east as Java and Bali, Borneo and the Phillippine islands, and Formosa.

(a) Indian Sub-region

(b) Ceylonese Sub-region

(c) Indo Chinese Sub-region

(d) Indo-Malayan

5. **Australian Region**—divided into :

(a) *Austro Malayan*, including islands from Celebes and Lombok on the west to Solomon Islands on the east.

(b) *Australian*, consisting of Australia and Tasmania
(c) *Polynesian*, consisting of all tropical Pacific Islands
(d) *New Zealand with Auckland*, Chatham and Norfolk Islands.

6. **Neotropical Region**—divided into:
   (a) Great Central Mass of South America
   (b) Chilian Sub-region
   (c) Mexican sub-region, consisting of Central America and Southern Mexico
   (d) Antillian Sub-region, consisting of the west India Islands

Palaearctic Region:

This region is of immense extent, comprising all the temperate portions of the great Eastern Continents—it thus extends from Azores and Canary Islands on the west to Japan on the east—a distance not far short of half the circumference of the globe. Yet so great is the Zoological unity of this vast tract that the majority of the genera of animals in countries so far remote as Great Britain and Northern Japan are identical.

Northern Africa and Arabia upto the Tropic of Cancer are excluded in this region, and the Mediterranean is ignored as a boundary—it is probable that there was direct land connection between Europe and North Africa during the Peistocene period, and the great line of sandy deserts formed a far more efficient barrier to the dispersal of species than the Mediterranean. In Asia the Himalayas form an efficient barrier between Tibet and India. None of the larger groups of animals, no order or even families are absolutely confined to this region. Comparing it with the only other wholly temperate region, the Nearctic, we find a much greater variety of types of mammalia and birds—entire family of Moles, Badger, Otter, Himalayan Panda, Seal, and Racoon Dog amongst the Carnivora; Camels, Deer, Antelopes, Sheep, Goats, Yak of Tibet, Elk, Bos or Wild Bull amongst the Ungulata; Talpa, Shrew, Hedgehog, Bear, and Dormouse amongst other mammals.

For birds Sclater has remarked, "It can not be denied that the ornithology of the Palaearctic region is more easily characterized by what it has not than by what it has." The Pheasants, Robins, Magpies, Grouse, Chough, Thrushes, House sparrows, Snow-buntings, Wagtails, Warblers; Ptarmigan, Ruff with fine collar of plumes that adorn them, are highly characteristic.

Tropidonatus, Vipers, Sandlizards, and Anguis amongst reptiles; and Proteus, Alytes, Frogs, Toads, Triton and Hyla among Amphibia are endemic.

Nearctic Region :

Consists almost wholly of temperate North America. The region possesses every variety of climate between arctic and tropical, extensive forests and vast prairies; a greatly varied surface and a rich and beautiful flora. It extends far towards the north, and there it reaches its greatest width; while in its southern and warmest portion it suddenly narrows.

Because of the position of its mountain ranges and the direction of prevalent winds, a large extent of its interior, east of Rocky Mountains, is bare and arid and often desert, while the most favoured districts bear but a small proportion of its whole area. It was also subjected to a very severe glacial epoch at a very recent period geologically, and exterminated a large number of animals which previously inhabited it. The region is, therefore, less rich and varied in its forms.

Moles, Otter, Texas, Seals, Goat-like Antelopes, hollow-horned ruminants, Bisons, Musksheep, Ground squirrel, Rats, Prairie dogs, Tree-porcupines, Bears, Flying Squirrels, Beavers, Marmots, Skunk, Elk, Racoon and Oppossums (Didelphys) are characteristic.

Birds are not very numerous—Blue jays and Turkey-buzzards, Crested partridges, Grouse, Finches, Thrushes, Humming Birds, Passenger Pigeons, Wood-Warbles, Greenlets and Hangnests are truly endemic.

Amongst reptiles a considerable number of genera are peculiar—glass-snakes, horned-toads, Iguana, Rattle-snakes, Tortoises, Gecko.

The region is very rich in amphibia—Siren, Amphiuma, Salamanders, Proteus, Necturus, Hyla, Frogs and Toads and Axolotl; and numerous freshwater fishes, including Amia, Lepidosteus and Acipensor.

Ethiopian Region :

Constituted by the whole of Africa and Arabia, south of Tropic of Cancer, together with Madagascar, Mauritius, Bourbon and Seychelles. The region is bounded by sea on west, south, and east, but on the north it is perfectly continuous with the Palæarctic region.

It is one of the best defined of the great Zoological regions. Interior tropical Africa has open pasture lands, hot and dry climate and grassy vegetation; the whole of the west coast is dense forest, and many of the more remarkable African types are found alone there; South Africa has the richest vegetation; whereas Madagascar is most isolated, and during the long period of time this island has served as a refuge for groups that have been dying out on the great continent.

Among the animals most characteristic of this region and not found elsewhere are the Gorilla, the Chimpanzee, several Baboons, and the large majority of lemurs; several peculiar Insectivora, such as the Golden Moles and the River shrew; the African Elephant, the Hippopotamus, Rhinoceros. Zebras, Buffaloes and Quaggas, the Giraffe the Aardvark, and many species of Antelopes; numerous snakes and crocodiles; several fresh-water fishes including the Protopterus and Polypterus and Lepidosteous; Lions, Leopards, Panthers, Hyænas; and Ostriches (African Ostrich or Struthio).

The region is also characterized by the total absence of Bears, Moles, Camels, Deer, Goats; Sheep, wild Ox, and wild Boar.

Oriental Region :

Consists of India, Burma, Siam, South Eastern China, and certain islands of "East-Indian Archipelago" (Sumatra, Java, Borneo, and the Philippines). It is separated from the Palaearctic region by the Himalayas and the Indus. The south-eastern boundary is an imaginary line, known as 'Wallace's line', between Bali and Lombok, between Borneo and Celebes and finally to the east of the Philippines.

The whole southern slopes of Himalayas with Burma Siam and the Western China, as well as Malay Peninsula are almost everywhere covered with tropical forests of the most luxuriant character.

The resemblance to the Ethiopean region are numerous and striking--Elephants, Rhinoceros, Higher Apes—Lemurs and Manis; whereas the presence of deers, bears, sheep and goats furnishes a characteristic difference.

The most characteristic members of the oriental fauna are :

The Orang-utangs, Gibbons, and numerous long-armed apes, extraordinary long-nosed Monkeys, Tigers, several Bears and Civets, the Indian Elephant, the Indian Tapir, 3 species of Rhinoceros, and Mouse-deer. The region is very rich in Insectivora and possesses several remarkable forms—Flying Lemurs, Hedgehogs, Scaly Anteater etc. Amongst reptiles the Ground-snakes, Fresh-water snakes Tree snakes, Pythons, Rock-snakes, Cobras and Pit-Vipers are all abundant and characteristic; Water Lizards, Geckos, Eastern Iguanas are most universal; fresh water tortoises, crocodiles and Gaviales are tolerably abundant: There are large varieties of fresh-water fishes—Ophiocephalus, Sacchobranchus, Notopterus, Siluridae, and Cyprinidae are universal.

The region is characterized by the presence of several large and gallinacious birds: Peacocks, Argus, Pheasants, Jungle fowl, Glossy Mynahs, Bulbuls, Sunbirds, Flower-peckers, Woodpeckers, Barbels and Cuckoos of peculiar and remarkable forms.

Australian Region.

The Australian is the great insular region of the earth. As a whole it is one of the best marked, and has even been considered to be equal in Zoological value to all the rest of the globe. It consists of Australia and New Guinea, New Zealand, Austro-Malayan and Polynesian Islands scattered over the Pacific, and Tasmania.

This region, after having been united with the Northern continent at a very early date, has ever since remained more or less completely isolated, and thus exhibits the development of a primeval type of mammals, almost wholly uninfluenced by any incursions of a later and higher type. It is thus unique among all the great divisions of the earth.

Very peculiar and striking features characterize the Australian region. It is distinguished from all the rest of the globe by the entire absence of all the orders of non-aquatic mammalia except two—Chiroptera and Rodentia, which are all of small size. In place of Quadrumana, Carnivora, and Ungulates, that abound in endless variety in all the other regions under equally favourable conditions, Austalia possesses two sub-classes—Marsupalia and Monotremata, found nowhere else on the globe except a single family of Marsupalia in America—the Didelphys. Primeval forms of Marsupials abounded in Europe during the Secondary Epoch, and supplied Australia with the ancestors of the present fauna The Marsupials are wonderfully developed in Australia—some are carnivorous, some herbivorous; some arboreal, others terrestrial; some resemble wolves, others marmots, weasels, squirrels, flying squirrels, and dormice. Monotremes are represented by two rare and very remarkable forms, Ornithorhyncus and Echidna.

Equally striking is the number and peculiarity of endemic birds : Emu, Kiwi and the Australian Ostrich and a large proportion of other flightless birds; Birds of Paradise Lyre-Birds, Honey Suckers, the Mound-Builders and Cassowaries are strictly peculiar and place the Australian region in the first rank for variety. Parrots, King-Fishers, Pigeons, and Cuckatoos are also in large numbers. There is, however, total absence of Vultures, Pheasants, Wood-peckers, Bulbuls, and Barbets.

One of the three species of Dipnoi, the Ceratodus, is found in the rivers of Queensland, and there are other fresh-water fishes—Siluridae and Mugillidae.

There is no family of snakes confined to this region but the many peculiar genera of the families pythonidae and Elapidae—the latter are all poisonous, so that, although Rattle-snakes and Vipers are absent, there are perhaps a large proportion of poisonous to harmless snakes. Scinks and Geckos form the bulk of Australian Lizards. Hatteria is the most extraordinary and interesting reptile of New Zealand. It is intermediate in structure between lizards and crocodiles, and also has bird-like characters in the form of its ribs.

There are no tailed amphibians in the whole of the region, but frogs and toads are known to inhabit some part or other of it.

The region thus shows a considerable deficiency both in families of Vertebrates and genera of Mammalia, as compared with the Oriental and Ethiopean regions, while in genera of birds it is a little superior in total numbers and considerably so in its peculiar types.

Neotropical Region :

It is an immense tract of land presenting such well-marked faunal characteristics as make it one of the best marked of all the Zoo-geographical regions. It includes the tropical part of North America, as well as the whole South American continent, the West Indies, the Galapagos Islands, the Falkland Islands, and Juan Fernandez.

Richness combined with isolation is the predominant feature of this region. During Miocene and Pliocene there was complete separation of North America and South America. Union with the North took place before the coming of the Glacial Epoch Even during the secondary times it was not united with any other continent except North America when ancestors of Edentates and Rodents passed into it. In early Tertiary times it received the ancestors of its monkeys and Marmosets and peculiar forms of Carnivora; and before the Glacial period it received the Tapirs, Opossums, Antelopes, Deer, Horses, and Peccaries etc. All these indicate a very remote origin. A long continued isolation of South America from the rest of the globe is required to account for the preservation and development of so many distinct groups of comparatively low type of quadrupeds and didelphys.

The region has no insectivora and no oxen or sheep, and usually no form of Ruminant except Deer, and Lama; neither a single form of non-ruminant Ungulate except the Tapir and Peccary. Crows and Ravens are totally unrepresented.

The region is characterized by wonderful family of Humming Birds, 3 species of Rhea, Toucons, Screamers, Oil Bird, Hoatzin, Cock and Rock.

The region is very rich in varied forms of reptile life, and the species are very abundant—wide average distribution of the families of snakes, Heloderma, Iguana Alligators, Crocodiles, Turtles, Boas and Rattle snakes;

The Cæcilians, Hyla, Piper, Rana, and Bufo are characteristic of amphibians. '

The great rivers of Tropical America abound in fish of many strange forms and peculiar types—Lepidosiren and Electric Eels.

There is a curious paralled between South America and Africa—Lower grade of Mammalian life i.e. Edentates, (Sloths, Armadillos and Ant-eaters,) and Rodents in one, Lemurs and Insectivora in other; Antelopes, Giraffe, Elephants, Rhinoceros, and Lion in Africa, and Deer, Pecarries, Tapir, Oppossums in South America, as also prerhensile tailed monkeys and Marmosets.

The region is excessively rich in insect-life, and butterflies surpass those of all other regions.

CHAPTER XXI

DISCONTINUOUS DISTRIBUTION

The distribution of life over the earth's surface is world wide, as no place is so forbidding as to be entirely without its flora and fauna—each has its quota of inhabitants, living out their lives as best they may.

Closer study however reveals the fact that the distribution of life is by no means a uniform one, and aside from differences in fauna due to climatic or other causes, there are peculiar instances of isolated distribution. There is much evidence to indicate that the great Asiatic land mass was for long a centre whence various animal stock originated and migrated to other regions. Thus Africa has elephants, antelopes, and great apes; while Brazil, with very similar environmental conditions, has none of these but instead possesses the tapirs, sloths, and prehensile tailed monkeys. The tapirs are found in central and South America, and again in Malaya Peninsula and Sumatra—a curious case of discontinuous distribution, explicable only by assuming that the American and Malaya Tapirs are the last survivers of a wide-spread race, whose intervening representatives have been blotted out.

Many cases of discontinuity in distribution may be explained by the former existence of land connections which no longer remain. The types in question once enjoyed a wide distribution, but the conditions favourable to survival have been found in widely separated places. It is not an uncommon thing for ancient and primitive groups of animals to have gone extinct everywhere except for definite small and isolated regions of the earth. All such animals are therefore examples of discontinuous geographical distribution.

Each of the southern landmasses contains one order of Ratitae (flightless birds) not found elsewhere: struthio in Africa; Rhea in South America; Emus, Cassowaries and Kiwi in Australia.

Similarly of the three living genera of Dipnoi, Protopterus is found in Africa, Caratodus in Australia, and Lepidosiren in South America.

The lemurs exhibit a very curious discontinuity—occurring in Africa (Madagascar) on the one hand, and in Southern Asia on the other. It has been suggested that a continent, 'Lemuria', existed in the Indian ocean. Similarly the Antarctic continent extended much further north than at the present day, so as to afford, with the aid of a chain of islands and co-operation of a mild antarctic climate, routes along which migration took place between south America and Australasia—thus an agreement between the fauna of Australia, New-Zealand and that of South America.

These cases of discontinuous distribution are readily explicable on the theory of evolution and migration: Either individuals of the species in question have occasionally transgressed the barriers to their dispersal and established new and distinct colonies, or possibily a large area of distribution has become broken up into a number of smaller ones by geographical or climatic changes, rendering portions of it uninhabitable.

Discontinuity in distribution of a species or other group is evidence of its antiquity.

ERRATA

Page	2	Line	29	read	Superseded for Superceded.
,,	21	,,	22	,,	by for bys.
,,	21	,,	24	,,	begin for egin.
,,	21	,,	24 & 25	,,	experiments for ex-hemqperiments.
,,	21	,,	last	,,	them for th.
,,	25	,,	10	,,	Imperceptible for Inperceptible.
,,	28	,,	27	,,	Supernumerary for Supernumery.
,,	37	,,	15	,,	Gemmules for Gemmles.
,,	42	,,	13	,,	analysed for analyzed.
,,	53	,,	4	,,	Which self-advertisement for which-self advertisement.
,,	82	,,	last	,,	percolate through for percolat ethrough.
,,	105	,,	20	,,	dispersal for dispersa.
,,	108	,,	6	,,	preserves for presents.
,,	109	,,	7	,,	Coincide for Concede.
,,	118	,,	12	,,	prehensile for prerhensile.